S. A. E. JOURNAL

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Seven National Meetings Scheduled

AS announced in Chronicle and Comment, and on the insert opposite p. 289, the Meetings Committee has announced Saranac Inn as the Summer Meeting place for 1929. The meeting will be held the last week in June, the dates being June 25 to 28, which will make it possible for members desiring to do so to extend their stay to the Fourth of July.

The action of the Meetings Committee, which was approved by the Council, was based largely on the vote of the members, Saranac having received the highest number of votes for first and second choice.

Six technical sessions will be arranged for the Summer Meeting; three by the Motor Vehicle Committee, one by the Transportation Committee, and two by the Meetings Committee. There will also be the usual number of committee meetings.

For the first time in several years it will be possible to include swimming events in the sports program, Saranac Inn facing the lake, where there are splendid facilities for swimming and diving.

Three National Aeronautic Meetings

The Aeronautic Committee is planning three National meetings during the year. The first will be in Detroit during the Aircraft Show, the dates being April 9 and 10; the second in Wichita during the Aircraft Show which will be held in June or July; and the third in Cleveland on Aug. 26 to 28, during the National Air Races.

WANTED: AN IDEA

Few members who saw the Chassis-Assembling Contest during the Summer Meeting at French Lick Springs in 1927 will ever forget it. Last year no special stunt was necessary; Quebec had enough sideshows. This year a special stunt is again in order. It can be on land or water or in the air. Can you help the Meetings Committee?

Production and Transportation Meetings

The Production Committee is planning to hold the Production Meeting during the National Machine-Tool Exposition, which will be held in Cleveland during the week of Sept. 30.

The Transportation Committee has indicated that the Annual Transportation Meeting will be held during the time of the Motor Transport Show, which is being planned by the National Automobile Chamber of Commerce. The time and place of the Show, and consequently of the meeting, have not been announced by the Chamber.

Annual Dinner and Meeting

The Meetings Committee is planning the Annual Dinner for the Thursday of Automobile Show week in New York City, as usual, and will hold the Annual Meeting in Detroit during the week preceding the Chicago Automobile Show, the dates being Jan. 21 to 24.

All of the Professional Activity Committees are at this time planning the technical programs for the various National meetings. Members of the Society who desire to suggest subjects for discussion at these meetings should communicate with the Society or with the chairmen of the respective committees. The arranging of the technical programs is very important, especially as the character of the papers published in the S.A.E. JOURNAL and in TRANSACTIONS depends largely upon the work of these committees. Appreciating the importance of this work, the Activities Committees are very desirous of receiving suggestions from members so that they can feel sure that the subjects decided upon are of the most interest to the related industries, and that the authors invited to submit papers are authorities in their respective fields.

National Meetings Calendar

Detroit Aeronautic Meeting
April 9 and 10
Book-Cadillac, Detroit

Summer Meeting
June 25 to 28
Saranac Inn, Saranac Lake, N. Y.

Western Aeronautic Meeting
June or July
Wichita, Kan.

Cleveland Aeronautic Meeting
Aug. 26 to 28
Hollenden Hotel, Cleveland

Production Meeting
Oct. 2 to 4
Hotel Cleveland, Cleveland

Transportation Meeting
October or November
Detroit, Cleveland or Chicago

Annual Dinner
Jan. 9, 1930
New York City

Annual Meeting
Jan. 21 to 24, 1930
Book-Cadillac, Detroit

Meetings Calendar

1929			MARCH			1929
SUN.	MON.	TUES.	WED.	THUR.	FRI.	SAT.
					1	2
3	4	5 BUFFALO CHICAGO	6 MILWAUKEE	7	8	9
10	11 CLEVELAND DETROIT	12	13 PENNSYLVANIA CANADIAN	14 INDIANA	15 SOUTHERN CALIFORNIA	16 NORTH WEST
17	18	19 DAYTON	20 NEW ENGLAND	21 METROPOLITAN	22	23
24	25 DETROIT	26	27	28	29	30

Aeronautic Meeting—April 9 and 10
Joint National and Detroit Section Meeting
(During Aircraft Show)—Book-Cadillac, Detroit

Summer Meeting—June 25 to 28
Saranac Inn, Saranac Lake, N. Y.

Buffalo Section—March 5
Lighter-Than-Air Ships—V. R. Jacobs, Goodyear Tire & Rubber Co.

Canadian Section—March 13
Crankcase Oil Dilution—H. C. Mougey, General Motors Corporation Research Laboratories

Chicago Section—March 12
Recent Flame Research—Prof. G. F. Clark, University of Illinois

Cleveland Section—March 11
Aeronautic Meeting and Dinner
Capt. L. M. Woolson, Aeronautical and Research Engineer, Packard Motor Car Co.

Dayton Section—March 19
The Development of the Fire Engine—Charles H. Fox, President and General Manager, Ahrens-Fox Fire Engine Co.

Detroit Section—March 11
Economics of Operation and Maintenance of Motor Vehicles—F. K. Glynn, American Telephone & Telegraph Co.

Detroit Section Body Division—March 25
This Body Business—R. E. Chamberlain, General Sales Manager, Packard Motor Car Co.

Indiana Section—March 14
Value and Advantages of Three-Speed and Four-Speed Transmissions—Howard E. Blood, President, Detroit Gear & Machine Co.; Samuel O. White, Chief Engineer, Warner Gear Co.

Metropolitan Section—March 21
Fuels and Lubricants Meeting—Neil MacCoull, The Texas Co.; Geo. A. Round, Vacuum Oil Co.

New England Section—March 20

Milwaukee Section—March 6
Diesel-Engine Meeting

Northwest Section—March 16
The Story of Petroleum—E. S. Evans, Standard Oil Co. of California

Pennsylvania Section—March 13
Automotive Diesel Engines—A. E. Canning, Chief Engineer, Stearns Laboratory, Cleveland
The Beardmore Diesel Engine—D. W. R. Morgan, Westinghouse Electric & Mfg. Co.

Southern California Section—March 15
Annual Dinner-Dance

Automotive Diesel Engines Near

Rapid Development in Next Year or Two Anticipated by Speakers at Southern California Section Meeting

DIESEL-engine development was reviewed and forecast in two prepared papers, two extemporaneous talks and general discussion at the Feb. 8 meeting of the Southern California Section at the City Club in Los Angeles. The dinner preceding the meeting was attended by 149 members and guests, and there were 155 at the technical session, at which Chairman Eustace B. Moore presided. At a short business meeting a Nominating Committee for Section officers for the year 1929-1930 was elected, as follows: Robert N. Reinhard, Chairman; Thomas A. Watson, J. F. Dixon, John Wiggers, and E. E. Tattersfield.

Eugene Power announced that, in connection with a membership drive, each member is to be regarded as a committee of one to bring in a new member. As many new members as possible are wanted because, under the Pacific Coast Transportation Committee and its Subcommittees, a large program is in prospect and there will be much real work to do.

Chairman William Fairbanks, of the Entertainment Committee, reported that it is planned to hold the Section's annual dinner-dance on March 15 in lieu of the regular monthly meeting.

Diesel-Engine Truck Tested

As the first scheduled speaker, L. T. Pockman, of the Chicago Pneumatic Tool Co., briefly reviewed his Diesel engine experience, outlined the principles of oil-engine operation, and described the air-injection and mechanical-injection methods of getting the fuel into the cylinders. Since 1910, he said, the United States has produced Diesel units aggregating more than 5,000,000 hp., and now is building Diesels at the rate of 4000 annually. Most of these range from 100 or 160 hp. upward. They are the salvation, he said, of the arid region of the Southwest, where electric power is not available. Copper plants in Arizona and Southern California are using Diesel installations ranging from 5000 to 15,000 hp., and the cost of power so generated compares favorably with that of electric power in the Los Angeles region.

High-speed, relatively light-weight Diesel engines are the result of the application of the oil engine first to the tractor, drag-line or power shovel, said Mr. Pockman. Reliable engines weighing 30 lb. per hp. or less are now being offered by many manufacturers. These are fairly comparable with heavy-duty gasoline truck engines which range from 12 to 28 lb. per hp. In a recent test run of a Diesel-engined truck from San Francisco to Los Angeles, 37 gal. of fuel oil was consumed, at a cost of $2, whereas about $12 worth of gasoline is required to run a conventional truck over this 450-mile route. The Diesel-engined truck carried a 5-ton load, maintained an average speed of 10 m.p.h., and averaged 12 miles per gal. of fuel.

Light Diesel Not a Dream

According to Mr. Pockman, motorcycles equipped with single-cylinder Diesel engines are being operated all over Continental Europe; and today a German or other Continental engine that can be put under the hood of a motor-vehicle is in the market. The full-Diesel type should be used for automotive purposes, he said, and a fuel-injection pressure of about 1500 lb. per sq. in. is desirable, with solid-fuel injection. The Diesel must use present equipment for cooling and starting. Less rather than more cooling water will be required than for the gasoline engine, and the present electric starter will start a small Diesel the same as it starts the conventional engine. The Diesel engine, he said, is easier to control than a gasoline engine of any type or size.

The light-weight Diesel engine that will meet these requirements is not a dream; every American and Continental Diesel-engine manufacturer is endeavoring to furnish it for automotive service, and Mr. Pockman prophesied that many of his hearers will be using such engines in their trucks next year. Even if the fuel vendor doubles or trebles the price of fuel oil when such engines become general, the truck users will still have the best of him, and although lubrication is more vital to the Diesel than to the gasoline engine, the operators can be sure that satisfactory service will be given.

L. A. Garrett, of Fairbanks, Morse & Co., next showed lantern slides of the two-cycle type of Diesel engine and gave a running description of it. His talk is not yet available for abstracting.

To Develop Aircraft Oil-Engine

The third speaker was L. M. Griffith, who has lately become vice-president and general manager of the Emsco Aero Engine Co., of Bell, Calif. In explanation of why he had made the change, he said that transportation by air in the future is certain to be by much larger aircraft than any of which we now know, and it can safely be said that we shall very shortly have airplanes with a carrying capacity of 75 passengers. These will require a large powerplant equipment. With the engines now available, they would require the installation of from 6 to 12 separate engines, which would make the airplane "look more like a Christmas tree than a thing of utility." Therefore, to him, the solution seems to be the development of larger power units, so that the airplane can have a single powerplant or at most three or four.

Passenger and bulk-merchandise transportation also calls for a reduction of the fire hazard to the minimum and for utilization of a fuel that is cheaper than gasoline. These requirements point to the Diesel engine. Although the problems are numerous and serious, he believes they are by no means insurmountable. They are going to be solved by careful research and development along the same lines that have yielded the progress of high-speed Diesel-engines to date.

European Diesels Reviewed

Mr. Griffith then surrendered the floor to E. T. Vincent, who recently joined the Emsco organization, coming from the Beardmore Co., of Great Britain, which has expended a great deal of money and effort in the development of the high-speed high-performance light-weight Diesel and secured results that point directly to the

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successful aircraft engine of this type. Slides were shown and brief descriptions given by Mr. Vincent of Beardmore engines to be used in the British airship R-101; in use on railroads in Canada, England, Spain, India and South America; the Mayback high-speed air-injection engine; the M.A.N. engine, which has a simple fuel atomizer; the Junkers two-cycle engine; and the McLaren-Benz and Bosch-Acro ante-combustion-chamber types.

Slides were also shown of charts of the performance of the Beardmore rail-car engines. These showed a fuel consumption of 0.354 lb. per b-hp.-hr. at 1000 r.p.m. and 102 lb. per sq. in. brake mean effective pressure, the maximum cylinder pressure not exceeding 800 lb. per sq. in. Working costs of the rail-cars on the Canadian National Railways, between Edmonton and Saskatoon, averaged 23 cents per train-mile as against $1.01 per train-mile for the steam train, according to Mr. Vincent, resulting in a saving of $93,677 on the 120,087 miles covered.

Pessimistic Views Refuted

Not all of the hearers of the addresses were so optimistic as the speakers regarding Diesel engines for motor-vehicles and aircraft. John Sturgess, research engineer of the Hughes Tool Co., said he "should hate to see a flapper out on a country road dependent on a Diesel engine," and stated that the solid-injection type still develops many weaknesses in the matter of getting an intimate mixture of the fuel with the air. He also said that, when using asphaltic-base oil, a deposit forms in the intricate arrangement of the injection nozzle, so that many Arizona operators of solid-injection engines find it necessary to use paraffin-base oil obtained from the East.

Mr. Pockman reiterated his belief that next year will bring forth many high-speed Diesel engines, and said that less skill is needed to run this type of engine than to operate a gasoline engine. In Los Angeles harbor, he said, 50 per cent of the boats are driven by Diesel engines run by foreigners "who never saw anything but a lateen sail." Diesel-engine-driven compressors are being sent by the large steel-erecting companies to Mexico, India, China and all over the world and employing natives to operate them who have never before seen an engine of any kind.

No Trouble with Asphaltic Fuel

Mr. Pockman disagreed with Mr. Sturgess regarding trouble with the fuel, saying he thinks that, so far as carbon is concerned, the asphalt or the paraffin base makes no difference with either the solid-injection or the air-injection engine. Mr. Vincent agreed with Mr. Pockman, saying that he had run the Beardmore solid-injection engine on various fuels, including ordinary crude boiler-oil, without making any change in the engine, and found no difference in operation except that consumption changed with the calorific value of the fuel, the total range being from 0.39 to 0.42 lb. per hp. Some engine makers recommend the use of ordinary boiler-oil in the engines in ships, and even a tar oil can be used.

Cost Compared with Gasoline Engine

Requested to compare the prices of Diesel and gasoline engines, Mr. Pockman gave the cost of Diesels ranging from 80 to 360 hp. as between $50 and $60 per hp. He thought the cost of the usual automobile engine of 45 or 50 hp. is about $30 per hp. The high-speed Diesel probably will cost double or treble this figure. Mr. Vincent pointed out that the Beardmore high-speed Diesel is really an aircraft engine and said he imagined that crude-oil aircraft engines will cost from 30 to 50 per cent more than gasoline aircraft engines.

Referring to the new Packard Diesel engine, which he had seen about six weeks previously, R. K. Havighorst said that the weight of an airplane driven by a gasoline engine and carrying a supply of gasoline sufficient for a 1000-mile flight will be about equal to that of a plane with a Diesel engine and its heavier oil. Mr. Vincent supplemented this with the remark that the British Air Ministry estimated that if the duration of flight exceeds 10 hr. the weight advantage lies with the Diesel engine even if it weighs 3½ lb. per b-hp. against 1¼ lb. for the gasoline engine.

Joseph Moore called attention to the importance of acceleration in the automobile engine and wanted to know how the Diesel compares with the gasoline engine in this respect. Mr. Vincent stated that the oil engine has about twice the acceleration rate of the gasoline engine. You can start the engine from stone cold on a frosty day and it will accelerate as rapidly as when hot; they pick up so rapidly, he said, that until people become used to them, the engines become very hot before they know it.

Asked by J. J. Murray, of the Aircraft Holding Corp., about the Packard engine, Mr. Havighorst stated that it is air-cooled, four-cycle and is not supercharged at present. Mr. Griffith added that a former associate of his who had seen and operated the engine was astounded by the way it handled; it seemed at least 25 per cent more active than any standard radial air-cooled carbureting engine. The Packard is a radial Diesel and takes air through a single valve in the cylinder-head; it compresses, ignites, expands, opens the valves, exhausts through the valve, holds the valve open and takes in the fresh charge through the same valve, he said. Adequate cooling of the valve is thus secured without depending on conduction of heat through the valve seat or stem.

Human Factor in Service Work

Metropolitan Section Members Analyze Problems of How to Satisfy Service-Station Customers

THE real job of service-station management is the same as that of any other shop or store which has something to sell; namely, to satisfy the customer, remarked H. R. Cobleigh, of the National Automobile Chamber of Commerce, at the joint meeting of the Automotive Service Association of New York with the Metropolitan Section of the Society, which was held at the Park Central Hotel, New York City, Feb. 14. "Maintenance means taking care of cars," said Mr. Cobleigh, "whereas service means taking care of car owners." It has been stated in another way, he said, to the effect that a genial mechanic with a hammer, screwdriver and a wrench, can render better service than the best-equipped shop in the world manned by grouches.

The dinner was attended by 160 members and guests, and 210 were present at the technical session, at which S. R. Dresser presided. Members elected to constitute the Nominating Committee of the Section are: Harold Nutt, J. J. Percivall, L. G. Nilson, A. C. Bergmann and L. J. Heinrich. Brief addresses were made by David Beecroft, vice-president of the Bendix Corp., and John F. Gfrorer, president of the Automotive Service Association of New York. The speakers who delivered prepared papers were W. J. Barrett, of the Metropolitan Life Insurance Co., on Enlightened Selfishness in Business; and Prof. G. U. Cleeton, of the Carnegie Institute of Technology, on the Psychology of Maintenance Service.

"Humanics" a Recent Study

It was brought out by Mr. Beecroft that the study of "humanics" by business management is of comparatively recent origin because, for approximately the last six years of our industrial history, we have been in a buyers' market; previously we were in a sellers' market. He defined a buyers' mar-

ket as meaning that the good quality of the merchandise itself is no longer an assurance of success, and that greater attention must be focused on the buyer to persuade him to buy. Success of the industry for the next few years will depend largely upon the ability of management to interpret correctly the characteristics of the human beings with whom it comes into contact in a business way, according to Mr. Beecroft.

Mr. Gfrorer paid a tribute to the mechanics who do the actual service work on cars. He remarked numerous instances within his experience in which he has observed these men working throughout their regular meal periods and late into the night in their effort to do their work well and satisfy the customer. He stated that the maxim of the Automotive Service Association is to make every person who comes into contact with its representatives feel friendly toward the product and the organization. Further, he has been in close contact with the personnel which conducts the service stations and controls service work in the Metropolitan District, and said that he knows an honest effort is being made by the personnel to protect every customer.

Importance of Human Contacts

Mr. Barrett said in part that human contacts are of extreme importance to the life insurance company. These are made through thousands of agents throughout the United States and, to the man or woman into whose home the agent goes he is the company. Questions asked of the agent are those which would be asked of an official of the company. It is therefore essential that the agent represent the company adequately, and that the company put the agents into a proper position to represent the company satisfactorily.

This is a day of competition of individual firms and also of the competition of industries. It is out of this competition of industries that the idea of service which is pervading every phase of industry today has grown. Adequate service, the building up in the mind of the customer of a proper conception of the intention and activities of the management of the company with which he is dealing, and the reflection he gets of these intentions and activities, constitute the measure by which he rates that particular company.

Summarizing the history of consolidations of some 20 firms over a period of years, Mr. Barrett said that 2 were successful and 18 were unsuccessful. These were largely financial consolidations. The reason assigned for the failures was that human relations in the industries concerned were not given sufficient consideration.

Employes Reflect Executives' Attitude

Mr. Barrett noted numerous instances in which the contact between the company and the public is often through some minor employe such as reception clerk, and that this person often is not competent, thereby creating false impressions in the minds of callers, and often engendering ill feeling. Similar results also follow ill-advised correspondence and are indicative of the attitude which pervades all the relations between the management and the public. For example, he mentioned that the attitude of one executive toward his employes was one of entire indifference, and said that, in this organization, comprising 800 employes, a person was immediately struck by the indifference of all the employes in their contacts with the customers. In his opinion, any program of training employes to maintain good relations with customers must have the full cooperation of the executive in charge. It is necessary that the person who comes into contact with the customer be in the proper frame of mind for making such a contact.

After explaining the method used by his company in making contact with the public, Mr. Barrett outlined the practices of some other large organizations such as public utilities, industrial companies, department stores, and the like. In conclusion he said that the car owner who has once established a satisfactory service-contact is loath to leave it as long as it continues to merit his confidence. A properly selected and trained personnel assures confidence. This attitude of the personnel emanates from the executive at the head of the business and reflects directly what his ideas are so far as the attitude of the company and that of the contact man toward the customer is concerned. The greatest asset that any business can have is a customer with whom its relations are on a permanent basis of mutual confidence.

Psychology of Maintenance Service

After describing briefly the work of the College of Industry at the Carnegie Institute of Technology, in which students are trained as foremen or minor executives, Professor Cleeton analyzed psychology as a science, as associated with fallacious philosophies, and as concerned with mental telepathy. He said in part that it has been found upon investigating modern industries that the factor most likely to be neglected is the one which has to do with persons. This applies, not only to the persons who constitute the public, but to those who compose the personnel of the industrial plant and who also must be considered by the executive in all his business dealings. One neglected factor which was discovered to be largely psychological, or human, is accident prevention. Professor Cleeton cited an instance in which an accident-prevention campaign had been carried on for five years but, because certain human factors had been neglected while conducting this campaign, it was possible for a specialist in accident prevention to reduce the number of accidents still further, so that within the succeeding year and a half the reduction was equal to the reduction in the previous five-year period.

Job for a Woe Man

With regard to service, Professor Cleeton stated that one of the factors involved is the mental attitude of the person who comes into the station. The first service job of the representative of the service station, in the speaker's opinion, should be to soothe the dissatisfied customer and change his mental attitude into a happier one. He suggested that it might be good policy for a service manager to hire someone to make it his business to listen to tales of woe. The psychology of this is based upon the fact that it is a human quality to desire sympathy; that is, when something goes wrong, it is human to want to tell someone about it. If the person to whom the tale is told listens receptively, the effect on the customer is soothing and beneficial.

Not only should the representative listen to complaints and to anything else the customer wants to say, but he should try in every way to make a good impression upon the customer, according to Professor Cleeton. Attention should be paid to the customer's own diagnosis of what it wrong with his car. Whether this diagnosis is right or wrong can be determined later; meanwhile, it may be very helpful. In service work, the contact between the sales department and the servicing department should be very close; otherwise, many misunderstandings may arise between the concern and the customer. Another point mentioned was the need for restoration in the mind of the customer of confidence which has been lost through the failure of some part of his car. This state of mind needs relief, and the customer is relieved if he believes that the mechanics in the service station are competent and that the work for which he is to pay will be well done.

Diagnosis with Apparatus Helps

Professor Cleeton suggested further that, when a diagnosis of trouble is being made in the presence of the customer, a psychological effect that is beneficial is created if mechanical devices for diagnosing trouble are used. This practice helps to create confidence that the diagnosing is being done with great exactitude; the customer is likely

to show interest and to ask questions concerning the devices and methods used and, in such cases, courteous explanations should be made. Another suggestion was that the customer be given more than he asks and pays for, in small ways such as cleaning the running-boards, the carpet and the windshield, before the car is finally turned over to the owner.

Servicing automobiles is essentially a merchandising problem of a peculiar sort, the speaker said. The selling of parts is important, but the customer is not interested in buying parts; he is interested in buying service, which includes parts. The service manager is selling service and labor, and the selling of these parts is incidental. In closing, Professor Cleeton emphasized how greatly human beings differ and how important it is that these differences in the characteristics of individuals be recognized.

Trends in Car Improvements

Indiana Section Members Review Developments as Revealed at New York and Chicago Shows

MEMBERS of the Indiana Section met at the Lincoln Hotel, Indianapolis, the evening of Feb. 14 for the regular monthly meeting, with Chairman Fred Duesenberg presiding. The Nominating Committee for Section officers for next year was selected as follows: Thomas J. Lítle, Jr., and George H. Freers, both of the Marmon Motor Car Co.; Col. William G. Wall; Ralph R. Teetor, of the Perfect Circle Co.; and D. McCall White.

Chairman Duesenberg announced that the April meeting of the Section is to be held at Hagerstown, Ind.

A paper on the trend of automobile design as observed at the recent National automobile shows in New York City and Chicago, by Delmar G. Roos, of the Studebaker Corp., who was prevented by illness from attending the meeting, was read by L. A. Chaminade, of the same corporation. After commenting on the great improvement noted in the appearance of recent models of cars, Mr. Roos stated that he is looking toward the establishment and maintenance of standardized and characteristic exteriors that may be retained by manufacturers, with minor changes, through many years.

More comfortable bodies, adjustable steering-gears, non-shatterable glass and improved door and window controls have made for increased passenger comfort. The increasing use of radiator shutters was cited among the mechanical advances, and straight-eight-cylinder engines were credited, as the result of an analysis, with the largest gains in the price field above $1,000, and sixes in the class under $1,000. While both overhead-valve and L-head engines had shown a gain during 1928, Mr. Roos anticipates an increase of the latter class of engines this year at the expense of the former type. There are two schools of automobile engine design, he holds; one advocating large displacement in proportion to size and weight of the car, combined with axle ratios below 4 to 1, and the other advocating power-plants of more than 5-to-1 compression-ratio combined with high axle-ratios ranging from 4 to 1 to 5 to 1. Mr. Roos inclines to the opinion that the trend is toward the former class. He also anticipates increased use of duplex carbureters, interchangeable bearings, and an increasing number of piston-rings, particularly where aluminum pistons are employed.

In the transmission field, the appearance of four-speed gearsets and the introduction of the synchro-mesh transmission were mentioned with some detail. So far as brakes are concerned, Mr. Roos noted a decided ascendancy of the internal type, with a tendency toward simplified hookups and better brake-lining; he also mentioned the desirability of larger braking-area on some of the small cars.

The greatly increased application of hydraulic shock-absorbers, improved spring-shackling, one-shot lubrication and wire wheels attracted the observer's attention at the shows. While there are no notable changes in axle design, Mr. Roos thinks that free-wheel suspension is certain to receive considerable attention in this Country within the next two years.

Trends in Chassis Design

Following the reading of Mr. Roos' paper, Wade Morton, of the Auburn Automobile Co., read a paper by Herbert C. Snow, who also was unable to be present. Prepared as a Review of the Automobile Shows, Mr. Snow's paper commented on present body trends, the practice of annual changes in radiator contours, and mentioned several interesting developments in the engine field, such as the Nash twin ignition, the Oldsmobile force-feed piston-pin lubrication, and the Pontiac method of counterweighting the crankshaft, with the harmonic balancer mounted outside the crankcase. It was noted that all straight-eight engines now use duplex carburetion, and comments were made on the improvements in crankcase ventilation.

Mr. Snow's review of the transmission dealt with the four-speed sets, the synchro-mesh design and the Noback device. Rear-axle tread is wider, in keeping with the tendency toward wider rear seats. Brake designs show a trend toward greater strength and heat-dissipating ability. The paper also reviewed various methods of strengthening chassis frames; deeper side-rails with wider flanges and, in some cases, reinforcing channels; the turning up or down of side-rail flanges; reinforcing angles used inside the side-rail in the kick-up over the rear axle, and the use of more and heavier cross-members.

Improved methods of spring shackling and increased use of hydraulic shock-absorbers were noted, as was the adoption by Nash and Graham-Paige of centralized chassis-lubrication. Among noteworthy refinements mentioned by Mr. Snow are the unified control introduced by Willys, the starter button on the Dodge instrument-board, and the Graham-Paige interconnection between choke and throttle.

Cars Can Be Made Lighter

Several important phases of car manufacturing were discussed by Thomas J. Lítle, Jr., who regretted that, owing to the high price of aluminum, less of this metal is used in engines today than some years ago. He anticipates the use of chromium for protection of wearing surfaces, such as cylinder-walls and bearings. As to the four-speed transmission, he said he believes that its use will be greatly extended during the coming season.

While it is good engineering to lighten structures, Mr. Lítle finds that few cars are as light as they were a year ago, yet that effect might be accomplished without aluminum, by using light-section crankcases and so forth to advantage, since, if the engine weight is reduced, the entire chassis structure can be made lighter.

He then spoke of the trend toward engines of eight and more cylinders, of the increased use of rubber for mounting purposes, and the tendency toward larger bodies. Non-shattering glass, he holds, must be further developed before it is suitable for general adoption. All in all, said Mr. Lítle, bodies are better looking and broader than in the past, with narrower windows giving a racy effect; adjustable seats are becoming rather popular; and broadcloth is taking the place of mohair in upholstery to no small extent.

Variety in Motorboat Engines

Chairman Duesenberg next called on Ralph R. Teetor, of the Perfect Circle Co., at whose cottage at Lake Wawasee several members of the Section had recently spent an enjoyable week-end and who is a motorboat enthusiast, to sum

up his impressions of the Motor Boat Show held in New York last January. Mr. Teetor was struck particularly, he said, with the variety of engines available, and with the radical departure in marine engines, many of which, he stated, run as low in weight-power ratio as airplane engines.

Chrysler and Lycoming, he stated, produce interesting motorboat engines. Outboard engines also are deserving of notice. The demand for and sales of motorboats are steadily increasing, and accordingly production on an assembly-line basis is being carried on by several boat builders.

Brakes Much Improved

When the meeting was thrown open for discussion, Colonel Wall remarked on the improvement of brakes in recent years, which has made faster automobiles possible. Increased decelerating ability has been gained by using larger drums and larger braking surfaces. When a car moving at 75 m.p.h. is brought to a halt by braking, a great deal of heat—probably the equivalent of between 3,000,000 and 5,000,000 ft-lb. —must be dissipated. Colonel Wall estimated that brake-drum temperature, under such circumstances, often rises momentarily to approximately 2000 deg. fahr., and said that the necessity of rapidly dissipating this heat must hereafter be given more attention than it has received in the past. When a car that travels at high speed is being stopped, the brake effectiveness often is found to be diminishing during the last part of the deceleration, because the brake-drum is expanding. With car weight tending to increase, braking ability must of course be increased.

Charles A. Trask, who for many years has devoted attention to developing the small car in America, outlined his ideas of a light modern car that will be convenient in traffic. It should be a four-cylinder car weighing less than 700 lb., giving approximately 45 miles per gal., and requiring only one change of motor oil in more than a year. With such a car, ease of manipulation in traffic and of parking are greatly increased, said Mr. Trask.

Mr. Teetor referred again to the piston-ring requirements of modern engines, pointing out the lack of rigidity of aluminum pistons at certain temperatures, when blow-by suddenly rises.

E. von Hambach, of the Carpenter Steel Co., then read a paper by Frank R. Palmer on The A, B, C of Stainless Steels. This gave a condensed summary of the properties of three types of corrosion-resisting steel. The first group has as its top limit about 14 per cent of chromium; and the second, as its lower limit, about 16 per cent; while steels containing between 14 and 16 per cent of chromium occupy a sort of no-man's-land and partake of the properties of both groups, stated the author. The percentages of other elements, such as carbon, in a given stainless steel are co-determinative as to the group in which the steel falls.

Body Problems Considered

Mercer Gives Cleveland Section His Views on Present and Future Construction and Discussion Follows

BODY design, construction and maintenance were discussed at length at the meeting of the Cleveland Section held Feb. 11 at the Cleveland Hotel, with Chairman Ferdinand Jehle in the chair. The meeting was well attended, 140 members and guests being present; and the animated discussion which followed when George J. Mercer, consulting body engineer, of Detroit, had read his paper after the regular Section business was disposed of, clearly evidenced the widespread interest in and the importance of the body question to the automotive industry.

A Section Nominating Committee consisting of five members was elected, as follows: S. L. Bradley, of the Ross Gear Co.; A. K. Brumbaugh, of the White Motor Co.; K. E. M. Karlson, of the Chandler-Cleveland Motors Corp.; F. W. Slack, of the Peerless Motor Car Corp., and A. A. Skinner, of the Leece-Neville Co.

Chairman Jehle announced the selection by the Governing Committee of B. B. Blair, of the Eaton Axle & Spring Co., as Secretary of the Section to succeed E. L. Allen, to whom it was voted to forward a message of congratulation and best wishes of the Section in his new appointment.

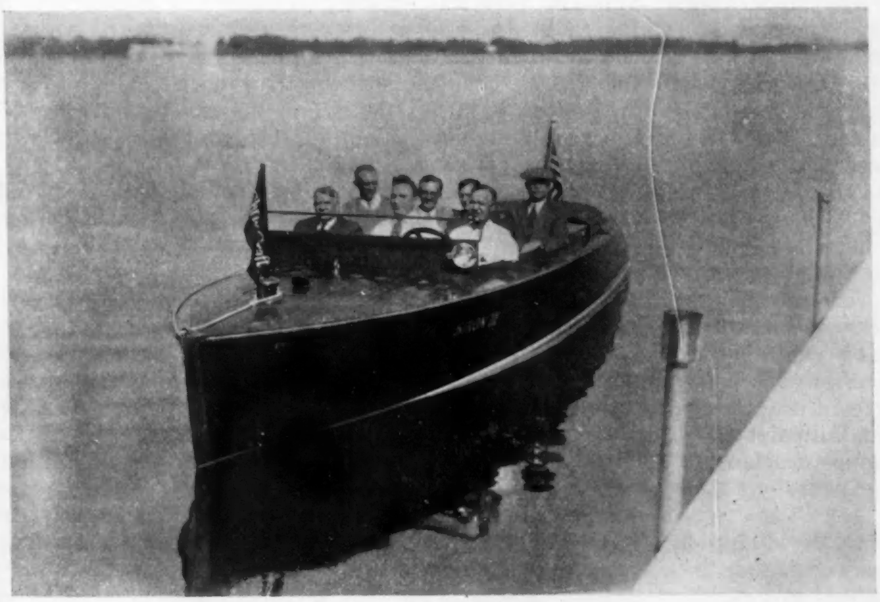
Bodies Reviewed and Forecast

Mr. Jehle then resigned the chair to L. L. Williams for the conduct of the remainder of the meeting. Upon being introduced, Mr. Mercer reviewed the development of the automobile body up to the present time and expressed the opinion that the all-steel body is really the body of the future. He said that bodies are better today than in the past; first, because more time, money and energy are expended in their production; and, second, because the body is today the best merchandising asset of the automobile salesman.

Car buyers, the speaker pointed out, neither know nor care much about technical details of new cars, since virtually all automobiles are now built to a good standard of performance; but prospective buyers are interested in bodies and their details because these matters arouse a sense of taste and style and appeal to their individual judgment.

After explaining several slides illustrating the development of car bodies, Mr. Mercer emphasized the present and future importance of composite bodies and stressed the need of universally providing comfortable seating

(*Continued on p. 346*)



Engineers Meet in Motorboat on Lake Wawasee

(Front Seat, Left to Right—Ralph R. Teetor, Daniel C. Teetor, Fred S. Duesenberg; (Rear Seat, Left to Right) F. F. Chandler, T. J. Litle, Jr., Harlow Hyde, C. A. Trask

Chronicle and Comment

Summer Meeting at Saranac

THE Meetings Committee, with the approval of the Council, announces the selection of Saranac Inn as the Summer Meeting place for 1929. Saranac Inn is located on Upper Saranac Lake in the heart of the Adirondack Mountains. It is isolated from all other communities, having its own railroad station. The Inn faces the lake; the cottages and bungalows, which because of their attractiveness will probably be at a premium, are within a few minutes' walk of the Inn. The first tee of the championship golf-course, for which Saranac is well known, is also within a short walk.

The dates decided upon by the Meetings Committee are June 25 to 28.

Wright Brothers Medal

THE Wright Brothers Medal, which is to be awarded annually by the Society for the best paper on aerodynamics, or structural theory or research, or airplane design or construction, presented at a meeting of the Society or a geographical Section thereof, during each calendar year, was originally designed with a monoplane on the obverse side. Feeling that this medal, which had its origin in the Dayton Section of the Society for the purpose of commemorating and perpetuating the work of Orville and Wilbur Wright and their pioneering on which the present success in aviation is based, should be symbolic of the first flight of a heavier-than-air machine with pilot, the Council of the Society authorized the changing of the design of the obverse side of the medal to show the Wright Brothers' Kitty Hawk airplane. It is anticipated that the next edition of the Wright Brothers Medal pamphlet, which will be issued shortly, will contain illustrations of the new and final medal-design.

The papers which are the basis for selecting the recipient of the medal for 1928 are in the hands of the Board of Award. The decision, including the time and place of the award, will be announced in due course.

Student Branches

THE Student Branch Committee of the Society, mentioned in the last issue of THE JOURNAL as to be organized, is to consist of one S.A.E. member; a member of the faculty, at each university at which an S.A.E. Student Branch has been or shall be organized; representatives of the Sections having headquarters nearest the Student Branches; and the Chairmen of the Membership and the Sections Committees of the Society. The Council has made appropriations to defray postage and other incidental expenses of the Student Branches.

The Student Branch Committee is to decide upon the details of the awarding of prizes each year for the best undergraduate-student papers presented at Student Branch meetings. At the last meeting of the Sections Committee the feeling was strong that the Student Branches should be fostered in every reasonable way. It is expected that arrangements will be made for prominent engineers to give addresses on automotive subjects at the leading engineering schools. The Society will collect and transmit to the Student Branches the local fees of students enrolled in groups, in the case of Student Branches which wish this done.

The 1929 Edition of the Handbook

THE 1929 edition of the S.A.E. HANDBOOK, which is now on the press, will be mailed to the members on or about March 20.

This edition contains the revised and new specifications approved at the Summer Meeting last June and issued in pamphlet form as a Supplement to the 1928 edition in September of last year, and also embodies the revisions and new specifications approved by the Standards Committee in January of this year.

Of particular interest are the new sections of aeronautic specifications and marine standards. It is anticipated that the growth of the aeronautic industry will make the aircraft section a predominant feature of the HANDBOOK.

Conference on AN Standards

THE importance of standardization to the aircraft industry was volubly expressed in the four-day AN Standards Conference, held at the Naval Aircraft Factory, Feb. 11 to 14. This annual affair, for which the host this year was the Navy, is bringing together the Air Corps of the two Services and effecting a standardization agreement on airplane materials, parts and accessories.

Manufacturers selling their products to the Army and the Navy are taking part in the conferences in increasing numbers, and through the coordination of the aeronautic standardization being accomplished by the S.A.E. Standards Committee with the AN standards work, mutual benefit is being obtained by the commercial-airplane manufacturer and user, and by the military services.

Details of the cooperation will be found in an article in Standardization Activities in this issue of THE JOURNAL.

New Riding-Qualities Research Projects

DESPITE the fact that riding comfort is one of the major considerations in both the engineering and purchasing of a motor-car, there is no fundamental knowledge, no common yardstick, by which to measure riding-qualities. Therefore, the Research Committee of the Society is sponsoring a program of riding-qualities research.

Under the direction of Prof. H. M. Jacklin, the Mechanical Engineering Department of Purdue University has undertaken to measure the vibratory motion of cars of various types and to collect statistical data on the "feelings" of a large number of persons after riding in these cars.

A second phase of the project goes further into fatigue as an evaluation of comfort. Dr. F. A. Moss,

of George Washington University, a well-known physician and experimental psychologist who has had a wide experience in measuring industrial fatigue, is starting on a program to develop a practical system which can be quickly and easily applied to the measurement of riding fatigue. It is intended that the system shall be made up of a number of definite methods of physical measurement, such as the proportion of carbon dioxide given off in the breath, changes in the blood such as the increase in lactic acid and the cell count, the difference in motor reactions and the efficiency of the sense organs, before and after long drives.

Detroit Section Passes 1000 Mark

THE Detroit Section now has the distinction of being not only the largest Section in the Society, but the first and only Section to pass the 1000 mark in Section membership. The one-thousandth Detroit Section member joined the Section on Feb. 11, the event being announced by J. R. Bartholomew, Chairman of the Detroit Section Membership Committee, at the meeting of the Detroit Section on that date. The Metropolitan Section is second, with 822 members.

Transactions, Part II, 1927

COMPILATION of material for TRANSACTIONS, Part II, 1927, is now in process and the volume will soon go to press. Included in this volume will be papers presented at National and Section meetings as published in the issues of THE JOURNAL from July to December, 1927, together with discussion on them printed during that period and subsequently and several contributed articles. There are 48 such papers as against 28 printed in TRANSACTIONS, Part I, 1927.

An announcement of the forthcoming volume is printed on an insert in this issue of the S.A.E. JOURNAL, facing p. 288. In accordance with the direction of the Council, copies of Part II will be mailed free of charge to all members of the Society upon request. A blank form for making such a request appears in the aforesaid announcement. Any member who desires to receive a copy of the new volume is requested to cut out the blank in the announcement, fill it in with name and address, and mail it to Society headquarters. This should be done even though a request has previously been made to receive all copies of TRANSACTIONS.

Sections Nominating Committees

A NOMINATING Committee has been chosen by each Section to name candidates for the Section offices to be voted on at the last meeting in each case of the Section administrative year. Members are to be elected by each Section to serve as Chairman, Vice-Chairman (or Vice-Chairmen), Secretary and Treasurer.

Sections Nominating Committees do not nominate members to serve on the National Sections Committee or on the National Nominating Committee. The Sections representatives of those two National Committees serve from January to January; that is, throughout the administrative year of the National Society. These representatives have already been chosen for the year 1929. The Sections representatives on those Committees for the year 1930 will be nominated from the floor at the 1930 Annual Meeting of the Society, or elected by the various Sections at their respective meetings next November.

Roster for 1929 Ready

EARLY this month the S.A.E. Roster for 1929 will be mailed to members who have ordered copies. Main divisions, as formerly, are the alphabetical register of members; the list of companies, with names of members associated with them; a geographical register of members; and an arrangement of members' names under lists of Army and Navy Departments, Government Bureaus, and universities and schools.

Officers, committee personnel and representatives of the Society and officers of the Sections for 1928-1929 are also listed.

A tabulation of the number of members residing in the various States is included in miscellaneous information; it shows that more than 5200 members are located in 11 States, as follows:

Michigan	1,271
New York	1,100
Ohio	624
Illinois	447
Pennsylvania	405
California	308
New Jersey	289
Indiana	281
Massachusetts	200
Wisconsin	182
Connecticut	136
Total for 11 States	5,243

Several hundred other members reside in 40 other States and in United States Possessions. In addition, the rolls include 183 Affiliate Member Representatives and 517 Enrolled Students. Members having their places of business in foreign countries number 411.

Manly Memorial Medal Fund

OPPORTUNITY is still open to those who wish to participate in the establishing of the Manly Memorial Medal Fund but who have overlooked the matter of sending in their subscriptions.

Following the announcement in the October, 1928, S.A.E. JOURNAL of the intention to create a fund for the endowment of the presentation annually of a medal as a tribute to the late Charles M. Manly, invitations were sent to all members of the Society to subscribe to the fund. Subscriptions are still being received. But the fund is not yet sufficient to pay the expense of administering the annual award.

The Council of the Society has approved the rules of award, and appointed Charles L. Lawrance, Henry M. Crane, and George W. Lewis as a Board of Judges to award the medal for the best paper pertaining to aeronautic powerplant development presented to the Society or any Section during 1928. A pamphlet setting forth the purpose and rules of award has gone to press and will be given wide distribution among men having aeronautic interests.

That there shall be no delay in the work of the sculptor, in the striking of the medal or in the preparation of the certificate, it will be necessary to realize the total sum of $8,000 within a short time. No doubt a considerable number of Mr. Manly's friends and associates fully intended to take part in establishing this fund but, through an oversight, have failed to subscribe. They may still do so by making checks payable to the Society of Automotive Engineers, Inc., and forwarding them to the New York office of the Society.

Development of the Outboard Engine

By Bruno Beckhard[1]

Buffalo Section Meeting Paper — *Illustrated with* Photograph

> Originally made only as a substitute for oars, the outboard engine has developed very rapidly during the last few years for sport and other uses.
>
> With the newer special boats, speeds have risen from 6 or 8 m.p.h. to 40 or 50 m.p.h. Outboard motorboat races attract thousands of entrants in a single season, and much of the improvement in engines is due to the racing drivers.
>
> Production now is sufficient to support and demand competent research work on the two-cycle engine and on the small high-speed hulls that differ so much from the boats with which marine architects are familiar.

NEARLY twenty years ago, cheerful Ole Evinrude, who was even then inclined to be stout, decided that it was foolish to sweat over a pair of oars whenever he wanted to go fishing, so he made an engine to push his boat. Then he took him a very lovely wife to run the business, and he grows more cheerful year by year.

After the Evinrude business was well under way, the Koban factory brought out the idea of two opposed cylinders. At about this time Mr. Evinrude sold his interest in the original Evinrude plant and took a five years' vacation. When he returned to the business it was to bring out the two-cylinder Elto.

Meanwhile, Lou Johnson came into the field. Now, while Mr. Evinrude is plump and easy going, Mr. Johnson is tall and a bunch of nerves; and there was almost exactly the same difference between the engines that they built. Evinrude engines were slow, extremely dependable and rather heavy, turning at from 700 to occasionaly 900 r.p.m. The Johnson engine was small, light and cleverly made, with a normal speed of 1700 to 2200 r.p.m.

These and other outboard engines were designed and sold for use on any boat, generally on small boats. But every boat has a latent speed, and the normal or latent speed of boats of this type was from 6 to 8 m.p.h. This was the field of the outboard engine as most people have come to know it; and, since the engines were intended for all sorts of boats and all sorts of people, the manufacturers' aim was to make a foolproof machine that did not require much tinkering. It was not until the advent of the high-speed engine that the buyers of outboard engines had any reason for inquiring about the works.

In 1925, F. T. Irgens, a young engineer, produced the first high-speed outboard engines in the Johnson plant. In July of that year outboard speed jumped from slightly over 10 to nearly 17 m.p.h.

New Problems with High Speeds

These first big engines were merely enlarged editions of the ordinary outboard engines of that time, but the change in size introduced new complications. For instance, the vertical driveshaft of the old engines was in a round housing extending down to the gearbox in front of the propeller. It did not take long to find out that, when the speed reached 15 m.p.h., the water striking the front of this housing would climb and flood the boat. I first saw these engines about a month after they came out, and then they were covered with the most amazing collection of copper plates in an effort to produce some sort of a streamline. Later, when the engines went into production, a streamlined lower unit was an essential part of the design. Every now and then since, someone comes along with what is supposed to be a fast engine with a straight housing; and then we all sit around and wait for him to learn his lesson. I do not know whether we can say that water has a sense of humor, but when we go from the laboratory to actual operation we frequently find a joker.

The first big outboard engines brought us face to face with the problem of suitable boats. Up to that time all the engines had been of about the same size, and we had more or less the habit of attributing the speed to the engine. When we began trying the larger engines on various boats we found that most boats could not be pushed much faster than they had been going; that the only result of more power was to drag the boat deeper into the water. To utilize the increased power we needed boats that slide or plane along the surface, instead of going down into the water.

Research on Small Hulls Needed

Hull design should be a field for technical research, but so far it has not been so. Surprisingly little information is available on small hulls, and such experience as we have had is confused by pet theories, personalities, and often by the limitation of funds available at any one time. So far the naval architects have not been of much assistance to us. Their very training with larger units makes it hard for them to appreciate the importance of the minute details that have a considerable bearing on our hulls. Our progress has been a see-saw of improvement in the engine, improvement in the hull, further refinement in the engine, and changes in hulls to match the new engines. In fact, these changes have come so rapidly that it has been almost impossible for production to keep pace with

[1] M.S.A.E.—Outboard Motor Headquarters, Flushing, N. Y.

them. This in turn leads to a not uncommon situation in which our advertising and publicity are concerned largely with models that are already outgrown.

Also, production problems have absorbed most of the time of the engineers connected with the various factories, so that research work has been all too largely haphazard. As a matter of fact, we have had more real experimental work in connection with racing than in all the factories or technical establishments, and a great deal of the improvement that has been made can be traced to individual drivers.

Outboard engines with a few unimportant exceptions are two-cycle engines, and the two-cycle engine has long been a research orphan. The total production until recently did not warrant any considerable expenditure for research, and everybody has been too busy since production has increased. Thus, for example, we discovered as far back as 1925 that high speed completely changed the action of a two-cycle engine from spark control to gas control; and yet we are still making engines with a large, obvious and convenient spark-control handle while we hide the little throttle lever under the flywheel. The throttle was originally so placed to discourage its use because then it was merely a concession to popular demand, and any change in its postition had the effect of poisoning the engine. Why a slow-speed two-cycle engine should not respond to a throttle, while the high-speed job can be controlled perfectly by it, is one of the many questions still awaiting an answer.

FIG. 1—OUTBOARD-ENGINE-BOAT AT SPEED IN STILL WATER

AUTOMOBILE-ENGINE DESIGNERS WANTED

What is really happening is that the outboard engine is going through various stages that are familiar to men who were connected with the growth of the automobile; and that leads me to believe that, with a little further growth, we shall attract some of the men who have had experience in the larger field to help with some of our problems. For example, three outboard-engine manufacturers are using aluminum pistons this year for the first time. They know virtually nothing about them. In a sense, nobody does; for the actual conditions in a two-cycle engine at 3500 r.p.m. are more severe than in a four-cycle engine at 7000 r.p.m., if for no other reason than that there is no relief between explosions, and the difference is just enough so that we cannot "lift" the experience in one field and apply it with certainty in the other.

On the other hand, experience does mean something; for instance, in the matter of clearances. There is a fairly definite engineering practice in regard to clearances for aluminum pistons for automobile use. Each of the outboard-engine builders, however, is trying out his own theory, and these vary so much that it is hard to believe that all of them can be right. I am sometimes inclined to believe that the inherent characteristic of a two-cycle engine is that it goes in spite of what you do to it, not on account of what you do. Of course that is not strictly true, because everything that is done has an effect, and the problems are so many that progress can be made only step by step. We are working from one end of the engine to the other with factors that call for further study and that reflect constant improvement as rapidly as production schedules allow.

Except for one make, all outboard engines are ignited by flywheel-type magnetos. These not only have been improved to meet the increased load but have been made so they will operate under difficult conditions of use and abuse. No method has yet been discovered to protect the coil if it goes overboard in salt water; but ordinary moisture, rain, or even immersion in fresh water have no serious effect on the present ignition systems.

Salt water also places another limitation in that we must at all times provide against the possibility of galvanic action. This is a problem familiar to the marine-engine builder, although not a serious matter in the automobile field. When it is recalled that two pieces of similar aluminum will undergo some action in salt water that tends to braze their contacting surfaces to each other, whereas two slightly different alloys will tend to destroy each other, the need of reducing the number of parts that actually come into contact with the water will be understood.

BEARINGS, LUBRICATION AND COOLING

Among the unsettled questions are bearings and lubrication. Until last year there were only plain bearings, but now some of the engines are equipped with roller-bearings in the connecting-rods and roller or ball-bearings on the crankshaft. The Evinrude still

depends on splash lubrication, the new Lockwood takes the oil from the lower main-bearing and leads it through a special line to the upper bearing, and the Johnson has a very ingenious device whereby a certain amount of oil is led from the crankcase to the upper bearing by the suction of the intake manifold.

The gear reduction from the vertical driveshaft to the horizontal propeller-shaft has been fairly well worked out. The lower unit performs two functions besides that of a gear-housing, in that it provides the cooling circulation for the power head and acts as a rudder. The importance of proper streamlining is just beginning to be understood; it is a field in itself,

Shaft-driven pumps have been generally discarded in favor of some sort of syphon system. Two models this year take water in by pressure at the front of the lower unit and provide suction by discharging through a hollow propeller-shaft and holes at or near the base of the propeller blades.

While it is comparatively simple to provide plenty of water for cooling, it is doubtful whether the manufacturers have any idea of what the engines need in the matter of cooling. Some lead the water into the top of the cylinder, some into the bottom, and others bring the water through the exhaust manifold before it reaches the cylinder. None of them provides any control of the flow, and there is good reason to believe that in many instances there is too much cooling.

I shall not say anything about propellers except that we still have much to learn. I have yet to see a boat builder, engine manufacturer or even a propeller maker who would commit himself beyond the statement that the right propeller can be found only by trying and trying until a satisfactory one is found. As we have different types of wheel, there must be some differences in theory, but I have yet to find anything that suggests any scientific classification of propellers.

While it is comparatively easy to point out these various problems, it is not so simple to make clear the interrelation between them; yet each change we make calls for other changes. As a matter of fact, we are always confronted not merely by a question of making a change but of striking a balance with every change we make. To begin with, a balance is to be secured between boat and engine; there is a balance between power head and propeller, another between propeller and spark-plugs, and so on.

Special Spark-Plugs Developed

For a while spark-plugs were one of our most serious problems, the more so in that we could get little help from the spark-plug manufacturer. Standard equipment plugs in 1927 gave from 1 to $1\frac{1}{2}$ hr. running at full speed. Finally the manufacturers began to see that we might have some possibilities as a market, and they started to experiment. Up to that time plugs were either hot or cold, and what we apparently needed was a hot-cold plug.

The Moto-Meter Co. was the first to help us. The first experiments it made with us led to the rather interesting discovery that we were increasing our compression space—that is, losing compression—by the space inside the plugs to the extent of approximately 5 per cent. Nobody had ever paid any attention to this item before; in fact, the original problem of the spark-plug makers was pre-ignition. In increasing the cooling surface we found we were increasing the compression enough to increase the speed 80 to 100 r.p.m. Not unnaturally we all began to talk of "cold" plugs.

Right here is a splendid example of the laboratory functions of the race course. Our cold plugs worked beautifully on all except the pole boat. It happened time and again that the pole boat, which was obliged to start well down the course and collect the other boats so that they would all cross the line together, would be out with spark-plug trouble just after crossing the starting line. Now, the only factor that was at all different was that the pole boat was obliged to idle nearly twice as long as the others, and the spark-plugs fouled while the engine was running cool. Eventually both Moto-Meter and Champion evolved plugs that, while generally cool, were hot enough to burn off the excess of oil or otherwise prevent its reaching the points, and other companies now are experimenting along similar lines.

Our results concerning space lost in the spark-plug led to a check-up of the spaces in the power head, and the piston head has been modified to avoid unnecessary depressions.

Fuel and Oil Requirements

Fuel is another uncertain factor, doubly uncertain because of mixing oil with the gasoline. Many racing drivers express the opinion that they must use this or that mixture or gasoline, but I often have wondered whether they have the slightest idea of what they get. Laboratory tests seem to show the best results from ordinary gasoline and a fairly large amount of ethyl fluid, more than is commercially obtainable. On the other hand, the Florida drivers all insist that they must use ether, and other drivers want various high-test combinations. Obviously, ether interferes with the effciency of the oil, but we have found in racing that yacht-club gasoline stored near the water almost always contains a considerable amount of water, from condensation at night, and the ether acts as a dryer in wet gasoline. I have found time and again that some such experience lies back of the demand for ether.

Nearly everyone assumes that gasoline of any common brand is about the same as any other of approximately the same price, but we know that is not so. Every now and then we are obliged to go a couple of miles inland to get gasoline that will give us good results. Altitude may also make a difference in fuel requirements. We recently had an example of a driver coming to a seaboard race with some specially prepared fuel that he had been using successfully for months on a mountain lake. It proved absolutely useless, and he had to replace it with local gasoline.

Oil is becoming a more serious matter than gasoline. While there is no doubt that we burn part of the oil, most of it is used for lubrication; but, instead of using it over and over, we are in effect constantly pouring new oil through the engine. As the high-speed engines require rather more than a quart of oil to the gallon of gasoline, this item is somewhat expensive.

I have always taken the position that good results should be obtainable from the consistent use of any good oil. Yet it is only fair to point out that the only effort to provide an oil especially adapted to use with outboard engines has been made by the Enterprise Oil Co., of Buffalo. We have used its Duplex oil in all our experimental work at Flushing for the last two years; and, while I cannot say that some other oil might not have done as well, we have never in that time

had a lubrication failure, although such troubles are not uncommon with high-speed engines.

Sacrifices Made for Speed

Until very recently outboard engines were produced for ordinary service, which is quite different in its demands from racing service. We figure that the requirements of the average engine in what we might call summer-home use are a composite of speed, easy starting and reliability, with not more than perhaps 60 per cent of the full power that could be developed by the engine for racing. The racing driver sacrifices these other qualities for additional speed, and by his efforts has contributed more than a little to our knowledge of engines and the possibilities for improvement. There is no way of telling how many drivers are concerned in this sport, as there are hundreds of local races of which we have no record. In the sanctioned races of the American Power Boat Association, which by no means covers the entire field, there were over 2000 starters during 1927.

The question is frequently raised, Why not a four-cycle outboard engine? There is no answer. There are two four-cycle radial models now on the market in this Country, and a four-cycle two-cylinder engine is making its appearance in England. It is too early to say much about these engines, but there seems to be no good reason why an outboard outfit cannot be made with a four-cycle power-head; there is also no basis for assuming that a four-cycle engine would be any better or poorer than a two-cycle for this use. Meanwhile, the progress made during the last few years with two-cycle engines makes it seem that we have not yet exhausted the possibilities of that field.

Problems of the Small Hull

I have said very little about hulls, chiefly because they probably seem somewhat outside the field of automotive engineers. As a matter of fact, I am not sure that we can divorce the boat and the engine. Marine architects seem to know very little about the requirements in our field. Their experience is with hulls of fairly definite equilibrium, in which the weight of the live load is comparatively unimportant, whereas in our field the driver's weight often equals the combined weight of hull and powerplant, and the driver's weight refuses to stay put.

Inboard powerplants are placed well forward, and in some types of construction the weight is utilized to force the water up under the tail of the boat and thus help maintain the planing position. Our first speedboats were modeled along these lines, and used to travel with their bows well out of water; in fact, some people still think that such an angle is a sure sign of speed.

Presently some of us decided that a bow riding well out of the water could hardly contribute its share to the riding-qualities of the hull, and we tried cutting off the bow entirely. This actually gave us increased speed and led us to appreciate the importance of the part of the boat that actually comes in contact with the water. To the inexperienced eye the boat looks like a car body, but the part of the hull that actually supports the boat on the water is very definitely a chassis. It will be noticed in Fig. 1 that the actual planing surface has been reduced to a very few square feet. It looks flat, and it is called flat; but it is very carefully designed, first, to draw the water toward the transom and, second, to provide just enough lateral pressure to keep the boat upon its course. With boats travelling between 20 to 40 m.p.h., every change of line affects the stream of water flowing under the boat and the relation of this stream to the turning propeller. Also, we must not overlook the fact that varying winds, currents and waves cannot be ignored; we must have not merely the planing chassis but enough surface to support the boat when, for one reason or another, it comes out of planing position.

Rapid Progress Being Made

Please remember that it is only three or four years since outboard engines were in the joke class; yet the winner's time from Albany to New York City, a distance of approximately 133 miles, during the outboard races in April, 1928, was 4 hr. 27 min. Anyone who has ever tried to drive a motor-car from Albany to New York City on an April Sunday will agree with me, I think, that this is real performance. Furthermore, a 30-m.p.h. outboard boat costs only about $500, while a boat of the same speed with an inboard engine will cost $2,000 or $3,000. This, combined with the increasingly bad road-traffic conditions, explains our growing market. We still have much to learn and many improvements to make, but I respectfully submit that we are making progress.

Traffic Congestion

THERE is no accepted definition for traffic congestion. To the individual there is congestion when he is unable to proceed at his desired rate of travel. This, it will be accepted, varies between wide limits. In the Cleveland transport survey the condition of congestion was detected by the reduction of the normal free operating speed which it enforced.

Most commendable progress is being made in the States having the largest highway traffic in perfecting their arterial roads in ways that will largely do away with congestion. Widening to four lanes, the elimination of grade intersections, and by-passing city streets are the most effective methods. In this direction Massachusetts, Connecticut, New York and New Jersey have all made notable progress. The capacity of the four-lane road is remarkable. Commissioner Macdonald, of Connecticut, reports 37,000 vehicles per day carried on the four-lane Boston Post Road near Hartford, without serious difficulty.

The highway congestion problem can be met outside the metropolitan districts within a reasonable time. It is within these districts that the real problem exists, and to a considerable degree on roads not on the Federal-aid or State systems. To carry traffic safely and quickly to and from the business districts of our larger cities is a real problem, and the expense involved is tremendous. Here again cooperative effort is the only means readily available, first to plan and, second, to execute.—Thomas H. MacDonald in *American Highways*.

Cost and Quantity in Airplane Manufacturing

By L. C. Milburn[1]

Chicago Aeronautic Meeting Paper — *Illustrated with* **Photograph**

> Curves showing the relationship between quantity and cost might be expected to drop smoothly from high cost for a few units until they approach a horizontal line of minimum cost. The author shows that, instead, they are irregular, because of factors like improved materials, tools and methods for fabrication, which make sudden changes when they are introduced.
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> To reduce sales resistance, it is necessary to fix prices on the predicted cost of an assumed quantity, according to the author; but a theoretical cost-curve extending beyond the range of practical experience may prove a snare because predicted costs often fail to be realized.
>
> Explanation and example are quoted for the tendency to adopt pressed-steel construction in place of wood and welded-steel tubing for quantities that justify the tool cost involved.
>
> Design, tooling and labor cost are said to be interrelated, and the amount of floor space required influences the manufacturing cost. Efficient time-scheduling brings parts to assembly at the right time, without storing. There is continual need of speeding up some lagging operation.

AMERICAN industrial success is built largely upon the fact that multiple, or mass, reproduction results in lower production costs. Occasionally we find cases in which even a unit loss is transformed to a net profit by the volume of business.

The relationship of cost to quantity was formerly more mysterious than it is now. Many persons have been faced with the necessity of predicting the effect upon cost that would result from variations in quantity, often reaching forward into quantities greater than have been produced before. Interesting facts in American industry have been brought to light by studies of past cost and production figures. One odd fact related recently by F. H. Colvin, of *American Machinist*, is that the labor cost of manufacturing an automobile in the $1500 class is less than one-half the cost of selling the same car. I mention this because of its bearing on the future manufacture and marketing of airplanes.

Another important feature about quantity brought out by Mr. Colvin is that, while the cost of making the automobile is reduced by increasing the multiple of reproduction, the cost of selling tends to increase as greater and greater quantities are urged upon the market. Nevertheless, it continues to be very desirable to reduce the cost of manufacturing, and I should like to take the simple theme of "larger quantity—less cost" and relate some of its peculiarities that I have noticed in connection with the production of airplanes in increasing quantity.

We frequently see graphs showing the relationship of cost to various quantities, in which the curve starts at a high point for the cost of one article and slopes away as the quantity increases. The ideal curve is smooth throughout and shows costs becoming always smaller and smaller as the quantity increases. In fact, this curve can be made so readily and it looks so smooth that it is something of a trap. It is very easy to imagine, from a study of this curve, that if quantities were increased it would be possible to reduce costs sufficiently to increase the demand enough to absorb the increased quantity. We should be a little cautious about any reasoning that sounds as slick as that.

As might be anticipated, the ideal curve is not reached in practice. The actual curves have jogs and bumps, hills and valleys. Many of the bumps do not result directly from production circumstances but from quantity procurement of materials or other independent causes, and I shall deal with only those which arise in the actual manufacture of airplanes.

Actual Quantity-Cost Curve Not Smooth

When cost depends on quantity and quantity depends on cost, there must be a certain amount of cutting and trying. Some years ago it was common practice to base selling prices on current costs, making reductions as occasion seemed to warrant. The fault of this policy is that it increases the sales resistance to be overcome because of reluctance of customers who anticipate lower prices. The more recent theory is to predict the extent of the market, compute costs upon this basis, and set prices according to these estimates.

This practice has followed naturally in the wake of huge quantity production, because when quantities become large the cost curve approaches more nearly its minimum and becomes almost a straight line. Then the entire cost-curve can be replaced by a horizontal line slightly higher on the scale of cost. In other words, the items that make the cost high in small quantities become less important as quantities increase. Ford, for example, would have been entirely unable to sell his new car if he had based the price upon the cost of

[1] Chief engineer, Glenn L. Martin Co., Cleveland (Now Baltimore, Md.)

the first 100,000. He was required to begin with a uniform price which would apply to his car when produced in millions.

Airplane manufacturing has only recently reached the stage of continuous production of definite models, and many airplanes still are sold on a scale of prices graduated in proportion to quantity. It is doubtful if any airplane now in continuous production has reached the horizontal, or the minimum, portion of its cost curve.

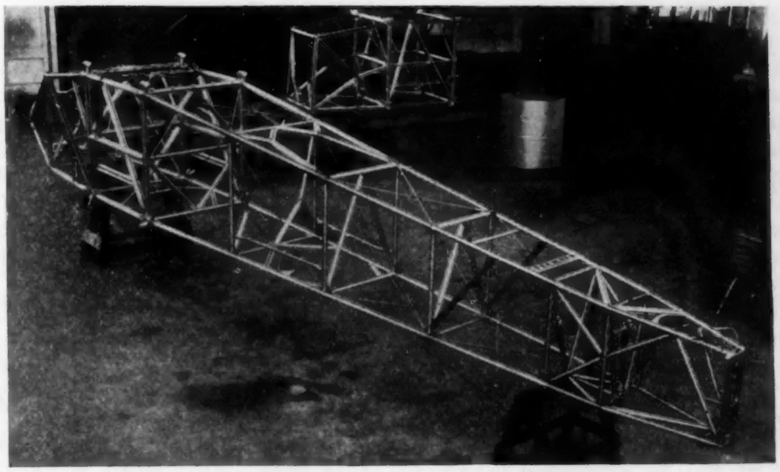

Fig. 1—Fuselage Framework Suitable for Quantity Production

Quantity Affects Choice of Material

The high cost of small quantities is well understood. Design, development and tooling costs keep this part of the cost curve high. Between this and the horizontal portion of the curve are a number of important influences to consider. One of the most important of these is the influence of material selected for the various parts of the airplane. Material may have much to do with the failure of the actual-cost curve to correspond to the ideal curve. Wood, for example, was used generally in 1918 because it was well adapted to rapid development work, and changes of model can be made easily in wood. But wood rapidly lost favor as quantity increased.

Although wood has an excellent strength-weight ratio and is amply durable for airplane construction in ordinary climates, it has two very important faults for quantity production: its quality is not uniform and its dimensions change with moisture content. Both of these faults are directly opposed to the smooth flow of processes that is so essential for rapid production. Many a wing-shop foreman has cursed a hidden pitch-pocket found by a vigilant inspector in some vital part of a nearly finished wing-frame, and many an assembly foreman has sung verses of the same song when trying to assemble fabricated wood parts that had warped or shrunk out of shape.

Riveted Sheet-Metal Reduces Cost

The material must be suited to rapid methods. Consider the welded tubular structures that have been so popular during the last 10 years. The complicated nature of airplane body, wing and under-gear frames makes it extremely difficult to employ automatic-machine welding on enough parts to make the application worth while. The welding is done largely with hand torches, and the cost results are satisfactory so long as the quantities are not large. But when large quantities are built continuously it is found that the speed with which completed airplanes can be turned out depends upon a hand process that can be speeded up only at the expense of large capital outlay for floor space, welding equipment and fixtures. Also the process interruptions during sub-assembly and final assembly, caused by cracks and misalignment resulting from welding, correspond in their effect on the cost curve to the flaws found in the wood.

Many designers and manufacturers have analyzed the influences that keep the cost curve from sloping downward and have realized that the basic material used has an important bearing, as to both its characteristics and the methods that can be employed to fabricate it. There has been a pronounced tendency during recent years to employ sheet material, usually of light alloy, joined by rivets or screws. The structural design chosen has an influence on this that is important, but not nearly so vital as the fact that the material is uniform and lends itself readily to machine forming-operations and rapid-fabrication methods. A specific instance of the results of a change in design occurred at the Martin factory recently.

During the construction of about 200 large airplanes having welded-steel fuselages, the whole production schedule was timed to the production of fuselage frames. However, during the production of an additional 100 planes, of a similar type but having a fuselage frame of light-alloy structural shapes formed from sheet and riveted together, we found that the progress of production was no longer geared to the output of fuselage frames. Instead, the frames accumulated faster than they could be used and had to be stored until needed, and the floor space and labor which had been used for producing fuselages was utilized to advantage to speed up other parts.

The introduction of lacquer has given such a strong object-lesson in the effect of finishing materials upon production speed that I believe it is unnecessary to further emphasize the importance of the correct choice of materials for protective coatings.

Importance of Design

The second important influence to consider is the design. I assume that everyone is familiar with the reduction in labor cost which can be accomplished by thoughtful design; and, while I do not wish to go into this lengthy topic very deeply, some points of interest may be mentioned. The designer should have in mind the quantity to be manufactured. Present quantities warrant liberal use of machine stampings; in a recent model we found that forged wing-fittings were economical to replace built-up welded fittings.

As a rule, we have found that favorable costs will result when all detail parts are designed for multiple production by machine-tools and for quick and easy assembly. The nearer an operation is to final assembly, the more important it becomes to ensure against interruption. The designer can aid greatly in this by choice of

material and detail arrangement of the component parts, particularly the joints and connections. The fuselage framework shown in Fig. 1 is an example of a design well suited for rapid production by machine methods.

Design, Tooling and Labor Cost Interrelated

The subject of tooling is also closely connected with design. In fact design, tooling and labor cost form three sides of a triangle, each influenced greatly by the other two. It often happens that quantities become large enough to warrant die expense for certain parts. When this stage is reached, the designer is able to make changes which both simplify the parts and improve their utility. It sometimes happens that, with slight changes, two different parts can be made alike or nearly alike, justifying the cost of a single die when two dies would not be economical.

When quantities become large, the labor charge per piece is more important than the design and tooling cost, and it becomes profitable to spend more time on these items. This condition has presented a hard problem in recent airplane manufacturing because of the difficulty of predicting quantity and cost. If a certain model is tooled for a conservative output and subsequently becomes popular, it may be necessary to decide whether it is better to interrupt production for retooling at a critical time, or to continue with a tooling set-up planned for smaller quantities. Overtooling for a model which fails to find a big demand may also prove disastrous.

Floor space is closely allied with tooling in its effect on the cost curve. An over-supply of floor space increases overhead costs, while nothing is more costly than cramped quarters where operations must be carried on at a disadvantage.

The sequence of operations is closely related to floor-space requirements, and the time schedule of operations is in the same category. Perfect timing seldom is achieved because of the variation in the personnel efficiency of various departments. Aircraft manufacture is especially complicated in this respect. A change in design or material may entirely upset the coordination of departments. A major assembly which has been the laggard may become the leader in speed of production because of such a change.

The purpose of time-scheduling is to bring all sub-assemblies to the major and final assemblies at exactly the right time for use, avoiding both storing of surplus parts and delay occasioned by shortages; but, in practice, various operations jockey back and forth under a wide variety of influences, and it is necessary to analyze constantly and to speed up the slower operations. These limiting operations should always have the attention of the designer.

National Transportation Board Proposed

IT is inevitable that the railways, both steam and electric, will become extensive users of the motor-truck and motorcoach. They are now, and this use is growing rapidly; but there is a vast difference between a railroad and a motor-vehicle. This point is basic in all considerations of legislation governing the motor-vehicle, and the same principles cannot be applied to both and yet preserve the service that the motor-vehicle can render. The average man cannot buy a railroad and run it to suit himself, but he can buy a motor-vehicle and run it when and where he chooses, and pretty much at the cost he is willing to pay.

Thus, to deny a certificate of necessity to the motorcoach is as likely to put into congested centers many more private cars as to drive the would-be patron of other forms of transport. Or it may deny to that portion of the public unable to own a car a more convenient method of transportation—an invasion of the freedom of the road.

Is competition between different forms of transportation, for one of which the public is furnishing the roadway facilities, a proper cause for restrictive legislation?

Is it an acceptable public policy to grant through such legislation franchises to all those now operating but reserve the right to grant franchises to those who seek to establish a new service?

And has there been sufficient study and investigation by experts in highway transport to justify projecting the Federal Government into essentially local problems?

The proper reply to such questions is that the whole matter of coordination of transport facilities is very broad and continuing. It involves not only railways and highways but also waterways and airways. The subject should be given thorough study on this broad basis.

Under the Federal Government we have the Aeronautics Branch of the Department of Commerce, which regulates the operation of aircraft; and the Interstate Commerce Commission, with regulatory control over the railroads. Functioning under the War Department is the Inland Waterways Corporation, which recently has been charged with larger responsibilities in connection with the development of inland waterway facilities; and in the Department of Agriculture there is the Bureau of Public Roads, which is administering the Federal Highway Act in cooperation with the States, and is possessed of intimate knowledge of the Nation's highway facilities and the needs and problems of highway transportation. Here are four existing agencies of the Government, each charged with a particular interest in one branch of the transportation facilities of the Country.

Would it not be a very sensible and expedient thing to bring together these four agencies, and others perhaps—if there are others that should properly be included—into a coordinated scheme of action, to form, let us say, a National Transportation Board, to take up not only the matter of regulating interstate motorcoach and motor-truck transportation but also the vastly larger question of coordinating all our existing agencies of transportation in such a way as to promote the best utilization of each?

The various proposals for regulation of interstate traffic by motor-vehicle common-carriers that have recently been made—all of them—have been prompted by the purely selfish motives of this or that transportation interest. They have not been proposed in the interest of the public; and it is not likely that regulation undertaken in such a spirit and with such motives will result in furthering the public's best interests.—Thomas H. MacDonald, in *American Highways.*

The Relation of Time-Study to Production

By L. W. HASKELL[1]

PRODUCTION MEETING PAPER

ALTHOUGH time-study is an important element in the development of management in industry, it is not a panacea for all industrial ills, nor is it necessarily an economic arm, as profits may or may not be made without it; but, because of its fairness to all concerned, it should not be overlooked. It is essentially constructive in its function, for the following reasons: Its ultimate objective is to arrive at a standard time in which work can be done. This is reached only after each act and mechanism necessary to the completion of the work has been carefully analyzed, the conditions improved, all unnecessary work eliminated, and all acts essential to the job simplified as much as possible, giving skill, effort, fatigue and unavoidable delays their due consideration.

Its success as a basis for a wage incentive lies, not on the assumption that men must work harder, but in the fact that it induces them to work better with less waste motion and time, thereby reducing labor costs through a higher and more uniform rate of production.

It reduces the idle time of men and machinery, prevents the purchase of unnecessary new equipment, provides the accounting department with an accurate labor cost per unit of production, assures a higher quality of product, and improves labor conditions by assuring the employee a fair day's pay for a fair day's work.

As the pay envelope is, in the final analysis, the most important factor underlying good industrial relations, a wage-incentive plan that is of greatest benefit to both the employe and the employer is conducive to good business.

The discussion is concerned with the method of determining the correct time for an operation and the type of man set to take the time; the factor of fatigue; the basis of wage payment; adjustment of the rate when earnings are too low or too high; importance of gaining confidence of the workmen in the fairness of the time-study; savings effected in labor cost, and avoidance of the purchase of unnecessary machinery and construction of buildings. It is asserted that the Ford company's day-wage payment is based on time-study, and that time-study enters into the designing of machine-tools.

THE relation of time-study to industry is a field which research has not fully explored; in fact, it may be best to assume this to be the case with respect to the problem of time-study in all its aspects. I even question whether a definition of time-study that is acceptable to the scientific mind has yet been formulated; therefore, I shall treat of the practical application rather than the theoretical and scientific side of time-study.

Measurement of some sort is the beginning of all science and, as it progresses, the measurements become more accurate. Management has, consciously or unconsciously, been no exception to this rule. In many well-managed industries, time-study has become the yardstick and is used with precision, although such terms as "accuracy" and "precision" belong to Einstein's theory of relativity.

In the days before mass production, the foot, the inch and standard fractions thereof were sufficiently accurate linear measurements for most purposes, but today even 0.0001 in. is not fine enough to satisfy most engineers. So it was in former days; the division of time into hours and minutes was satisfactory and, to a large extent, it still is; but manufacturing methods and competition in business have made more precise measurements in time a necessity, and in time-study we have the minute divided into hundredths.

Very few persons appreciate the importance of time. The man who devotes himself to study of the utilization of time, and insists that his co-workers utilize their time without waste for productive purposes, is doing as much to elevate the standard of living as any other person or persons following any line of endeavor. It was undoubtedly a part of the great plan of things that man was created with an independent individuality and, with it, a varying amount of reasoning faculty. It seems that, through the economic conditions which are constantly becoming more complex, men are more dependent upon one another than ever before, and our mutual trust in one another is of paramount importance.

The public demands that we have dependable men. In an effort to make themselves more dependable, men have concentrated their studies and efforts on separate phases of this complex whole, and so have specialists. The ever-increasing number of specialists, together with the intensity of the degree of specialization, shows the trend of advance of civilization in this direction, and naturally we have the specialist in time-study.

A BASIC UNIT OF MEASUREMENT

The skill and thoroughness of the work of the time-study man are becoming more important to management, as time-study is now used as the basic unit of measurement for items such as machine loads, labor control, cost estimates, budgets, wage incentives, and many others.

Although time-study is an important element in the development of management in industry, it is not a panacea for all industrial ills, nor is it necessarily an economic arm, as profits may or may not be made without it; but, because of its fairness to all concerned, it should not be overlooked. It is essentially constructive in its functions, as it has for its ultimate objective the

[1] Superintendent of time-study, Dodge Bros. Corp., Detroit.

arriving at a standard time in which the work can be done. This standard is reached only after each act and mechanism necessary to the completion of the work has been carefully analyzed, the conditions improved, all unnecessary work eliminated and all acts essential to the job simplified as much as possible, giving skill, effort, fatigue and unavoidable delays their due consideration.

Induces Better Use of Time and Effort

Its success as a basis for a wage incentive lies, not on the assumption that men must work harder, but rather in the fact that it induces them to work better with less waste of motion and time, thereby reducing labor costs through a higher and more uniform rate of production. It reduces idle time of men and machinery by determining the proper operating force for a given schedule, and prevents the purchase of new equipment so long as machine-hours sufficient to meet the schedule are available. It provides the accounting department with an accurate labor cost per unit of production; maintains and assures a higher quality of product by aiding in the adoption of better methods; and improves labor conditions by releasing surplus men for other lines of endeavor, thereby assuring the employe a fair day's pay for a fair day's work.

In the final analysis, the pay envelope is the most important factor underlying good industrial relations. To the employe, it is the most vital fact connected with his job. It is essential that his wages provide him with a regular and adequate income. It is the very heart of all industrial relations; the success and prosperity of American industry is, to a large extent, the result of a just and adequate wage. To the employe and to the Country, it is equally essential that industry be conducted with the greatest efficiency, so that the cost of the finished product shall be at the minimum.

It is obvious, then, that a wage-incentive plan that is of maximum benefit to employe and employer alike, is conducive to good business. Many of these procedures have been developed in the past, and I believe all of them are good, as they have for the fundamental purposes the eliminating of waste and the increasing of the material welfare of a people, by returning to the employe a maximum wage and to the employer a minimum net unit cost.

THE DISCUSSION

Leighton Dunning[3]:—How do you determine the correct time for an operation, as regards the capabilities of the man? If several men are performing the same operation, do you pick out a particularly apt man and use a stop-watch in such a way that he cannot see it, or do you have a trained expert whom you set to work out the time privately?

L. W. Haskell:—In picking time-study men in a factory as big as the Dodge Brothers plant, we do not try to select men who will cover all branches of the industry. Preferably, I go into the shop and choose a machine setter who has a fair education, good power of analysis, and who knows a fair day's work when he sees it. I take him into the office and let him work with the older men for a few days to acquire the rudiments of time-study and learn how to figure and use the slide-rule, then we tell him to go out on to the floor.

When I took over time-study in the Dodge Brothers factory I had two unpleasant propositions to handle. The first was that the management asked me, "Do you know how to reduce prices?" That was right after 1921. "We want all these prices reduced 10 per cent," I was told. Naturally, one either carries out the orders of the boss or quits. We carried out his orders. About three months afterward the management said, "How long would it take you to take 10 per cent off of those prices?"

"I can go over the shop in two weeks," I replied, and was told to go ahead. When I walked through the shop I heard many such remarks as, "There goes that blankety-blink-blank ——," but it did not bother me, for I had a duty to perform to myself and to the company, and knew that if any injustice was done by this cutting I was in a position to correct the error.

Today those things are history. We do not make studies that way. We have men that are qualified for the job, whether it is in the machine-shop, trim shop, paint shop, foundry or drop-forge shop. They know the job as well as any operator or supervisor. They walk up to the man and say, "We have to get the time on this operation. Remember, we are fair. Our past moves were fair. It depends entirely upon yourself whether you want to be fair with us, but remember, it makes no difference whether you are or not, because with our levelling factor it makes little difference whether a man slows down or speeds up." Many of the men will speed up; men with nervous temperaments will naturally go faster. Others, with an ugly disposition, will work the other way. Consequently, it becomes necessary to have skilled men as time-study observers, for they know those conditions the minute they see them.

Method of Determining Normal Time

We take a stop-watch reading, using the snap-back method, and the number of cycles taken depends entirely upon the nature of the job. If it is a long, tedious operation we probably divide it into as many as 20 elements, and to check those 20 elements we take 5 continuous cycles on the running of the watch. We arrive at a normal time by the calibrating of the picked element by the time-study man at the rate of speed and the skill the operator is showing. To be fair all the way through, it became necessary to have a chart for fatigue allowances. As it was necessary to apply something that was quick, equitable and fair, I plotted on a graph the unit pounds of energy exerted, and if a man was under an 80-lb. load for 0.03 min. we allowed a certain percentage; if he was under a 180-lb. load for 5 min. that also carried a certain percentage. The fatigue percentage was added to the normal time and the total became our standard time. When we had ascertained this we felt that we had arrived at the quantity of production that was equivalent to the base rate which was set up by the management.

Our base rate is not a day rate, neither is it an earning rate, but only a monetary value set up for us to work to and by which to calibrate our standard time. Consequently, when we have a standard time on say a 65-cent

[3] M.S.A.E.—Manager, Detroit branch, John Warren Watson Co., Detroit.

base rate, we feel that the man must produce the specified number of pieces to be worth 65 cents an hour to the company.

MR. DUNNING:—Do you check up the observations of a workman with an expert later on?

MR. HASKELL:—No, sir.

BENSON REARK[3]:—In making a time-study, one item I bear in mind more than any other is that, if the man is dissatisfied with the standard production rates I set up, will the next man who takes the job, after a proper period of breaking in, be able to meet the standard that I set.

READJUSTMENT OF PAY RATE

C. R. WEISS[4]:—A great deal of the early development of time-study work was done in our Nicetown plant. In those days it was rather difficult. Such men as Fred Taylor and Carl G. Barth had great difficulty in selling to the manufacturer the idea that there was something back of the time-study principle. The Tabor Mfg. Co.'s plant in Philadelphia and the Link Belt Co.'s Nicetown plant were two of the first plants equipped with the Taylor system in the United States, I think. We spent a great deal of money on the system at that time, but we had faith in scientific management as applied to shop practice. It proved a money maker for us; it has been very successful and we have used a modification of it ever since in all of our plants.

First, to follow out Mr. Haskell's idea, the man who is going to set a rate must be familiar, not only with the theory, but with the applied practice on the particular machine-tool. Naturally, if an exceptionally brilliant workman is picked he will do things better than an average man would do them, but the theory of time-study is to set a fair rate for an average man as a base rate. Our policy was, once a rate was set, never to change the rate if a man made what we thought was too much money, because that would kill the incentive for doing the task. The most satisfactory way to readjust rates in the system-equipped plants is by the installation of more modern equipment, by means of which the man can do an operation or a series of operations in a shorter period. No workman has ever been reluctant to take a cut in rate if the available equipment enabled him to do this with less expenditure of effort.

Mr. Dunning asked how to set a time so that another workman would go along at about the same rate. We have probably 35,000 or 40,000 different time-study cards. The data have been compiled over 25 years of that sort of work. They are very instructive. To any man acquainted with shop practice it is like reading a treatise in a book; it is all there before him. The workman is presented with a copy of the analysis, and when he has surveyed that he is fairly satisfied that the scheme is right. This plan has been very successful in our plants.

K. W. STILLMAN[5]:—Those who heard John Younger[6] tell about the production methods used by the Ford Motor Co. will recall that Ford does not use time-study and thinks it is a more or less useless adjunct to management. It would be interesting to hear what some of the time-study men think of that.

L. W. HASKELL

L. A. BARON[7]:—The Ford company does use time-study; it time-studies all the operations, and the men have to keep up with the times set, but they are not paid on a piece-work basis. That is what I am told by men who have worked in the different Ford-branch assembly plants.

SLIDING SCALE CUTS LABOR COST

I should like to recite a case we had in our plant having to do with arbitrarily cutting down time. When we were working on a straight piece-work basis the average workman in the shop had the idea that if he made more than a certain rate of pay we would cut his rate. Last spring I induced the management to turn the time-study over to me, and, instead of studying the plant on a piece-work basis, we re-studied the output on a standard time basis and set a standard time whereby at every increase in earnings the man made we got our direct labor cheaper. The cut in our costs is not in direct ratio to the increase in a man's earnings; for a 7.5 per cent cut in our costs a man gets an increase in earnings of 32.16 per cent. We adopted a sliding scale and sold the men on the idea. We started them a department at a time and paid them for the time they were in conference when the plan was explained to them. We showed them that our standard costs were regular hourly rates plus 25 per cent for the time covered. That is, if a man's rate was 60 cents an hour, and time-study showed 60 min., our standard cost was 75 cents, and we convinced the men that they were not worth anything to us unless they were making 25 per cent or more above the day rate.

In this connection, I should like to emphasize the importance of getting a man to make the time-studies who has an agreeable personality. I hired a man who had had considerable shop experience and made him my time-study supervisor. He had served four years as an apprentice in the tool-room and worked three years

[3] Time-study, Hudson Motor Car Co., Detroit.

[4] Chief engineer, Link Belt Co., Indianapolis.

[5] Assistant editor, *Automotive Industries*, Philadelphia.

[6] See S.A.E. JOURNAL, December, 1928, p. 568.

[7] Comptroller, Stutz Motor Car Co. of America, Indianapolis.

as a toolmaker. He knows machine-shop practice from one end to the other and is something of an industrial engineer. We have to watch his work because the average workman will give him better time than the man can maintain hour in and hour out during the day. The supervisor has a personality that draws from the man the best there is in him. That is particularly true on machine-shop work. I place a great deal of emphasis on the personality of the man making the time-study, as we do not want to irritate the operator. We say to the operator, "We are going to make a time-study of you and we want good time on this operation. We know when you do not give us good time." And we usually get it.

Incidentally, in changing from the piece-work to the standard time-basis on the step-rate plan, we have saved in direct-labor costs, from Aug. 1 to Oct. 31, about $12,000 that we can lay our hands on.

Novice Should Not Make Time-Study

Mr. Haskell:—One statement was made in my paper that I do not want overlooked; that is that the time-study should not be made by a novice. In 1919 our time-study engineer turned in his report showing a saving of $3,000,000 a year. Two or three days afterward, he was called to the office and the manager said, "Mac, I see by your report that you have saved $3,000,000. For God's sake, what bank did you put it in?"

The next day we did not have any time-study department; the whole force of 92 time-study men was wiped out and the time-study was turned over to the foreman.

In defense of those two 10-per cent cuts I had to make, that condition of letting everybody set the time existed from 1919 to 1921, and I assure you that since we have taken over time-study and have tried to build it up on a scientific basis, being fair to the time-study man, to the workman and to ourselves, we have never found it necessary to make those cuts that hurt all of us. I want to leave this thought: that time-study, through its importance to mankind as a whole, should be handled by men who really know what they are doing.

Mr. Baron:—I mentioned how much we saved in three months, and I want to tell how we know how much we saved. We have always paid our men a guarantee on the day rate for the hourly rate; that is, we hire a man at a base rate of 60 cents an hour, and if he works 50 hr. in a week he is paid $30 whether he earns that much or not. At the end of June we had chalked up on our expense account approximately $8,000 as the day-rate guarantee paid to the men for the first six months of the year. That was the amount we had paid them in excess of their earnings on the piece-work price.

When we put into effect the standard time whereby we got our labor a little cheaper in accordance with the increased earnings of the men, we credited that saving against manufacturing expense to wipe out the day-rate guarantee that we had paid previously during the year. At the end of October we were showing a saving on the day-rate guarantee of $141.80. We had wiped out the $8,000 expense, had made a little saving, and had cut the direct-labor cost to make up the other $4,000 that made our $12,000 savings.

Errors Admitted and Corrected

J. C. Blue[8]:—About how long after a time-study rate is set would you allow it to remain, in case the men did not meet it?

Mr. Haskell:—If the foreman tells us that a man cannot make the rate, we analyze the job, in every way, checking it with our studies, and invariably we find that something else has gone wrong rather than the study, because, as a rule, they do not check; sometimes we find it is the flow of material. But, when we find we made an error, we correct it. We do not guarantee that we will not cut a rate, because I know from experience that when you guarantee something, you want to stand back of it regardless of the consequences. Men are prone to err. If we make an error, and a rate is too high, we walk right out to the workman and say, "A mistake has been made, and we are going to do this job all over again." The men know we are fair, and usually they do not object.

Mr. Baron:—We do somewhat the same thing; only, when we have made an error in favor of the men, we are not so quick to correct it, because the more money the man makes the cheaper we get our direct labor. I have had the same experience that Mr. Haskell has had; in many cases something else has gone wrong instead of the time-study. The particular thing that we have found on jobs in our plant that we have been asked to restudy and allow more time on has been insufficient allowance for fatigue. I think that proper allowance for fatigue is a very important item that must be considered in making time-studies. From my talks with industrial engineers, reading on the subject, and discussing it with men who have made literally millions of studies, I believe that the more highly repetitive a job is, the greater is the amount of time that must be allowed for fatigue. Once in a while we miscalculate that on very quick operations. Those are the ones that we have been called in to restudy and allow more time on, more often than on operations that take 8 or 10 min. It is operations that require less than 1 min. to perform that cause the greatest trouble in setting time allowances. That is on account of the fatigue factor.

Savings Extend Beyond Direct Labor

J. Charles Mottashed[9]:—I am inclined to believe that time-study men and other groups are overlooking big savings elsewhere in their eagerness to concentrate on direct labor saving. Our whole conversation seems to be on "direct labor" to the exclusion of other important avenues of savings.

Someone in an organization decides to buy a lot of new equipment, to build a new building, and a comprehensive plan of expansion is agreed upon. From time-study records we find that a certain machine is not needed, that the building need be only three instead of four stories and, before we get through, the time-study department has prevented the expenditure of some tens of thousands of dollars. So far I have heard no one touch on this phase of time-study work. It is certainly worth thinking and talking about.

After a number of years of experience in time-study engineering, I am beginning to believe that Mr. Gilbreth's technique of micro-motion study, with the selec-

[8] Superintendent of production, Firestone Tire & Rubber Co., Akron, Ohio.

[9] Superintendent of time-study, Hudson Motor Car Co., Detroit.

tion of the best man for observation and the transference of his skill to the mediocre and the poor man, is decidedly worthwhile.

Mr. Haskell, in his paper, did not confine himself simply to the question of wage cutting; he also emphasized machine-load equipment purchase and even standards for the employment department, by which they can determine man load.

If the Ford company does not use time-study, as we have been told, how does it predetermine the number of jobs that should come off the line during the day? How does it know that four lathes are needed instead of six, or six instead of four? It may not pay on a time-study basis, because it sets an arbitrary rate for a day's wage, but it is a foregone conclusion that the company buys equipment, constructs buildings and hires men because some time-study department, although it may not be called such, has supplied the information that makes it possible for these things to be done intelligently.

On the second page of Mr. Bouton's report[10] which is well worth reading, one of the subjects under consideration by your Time-Study Committee is Methods of Developing and Training Time-Study Men. I am pleased to say that the Society of Time-Study Engineers is sponsoring a class in time-study engineering under the auspices of the Detroit Department of Education. The class is now half way through its first semester and has an enrollment of about 35 students. Interest has been very well sustained. A. C. McClure, secretary of the Society of Time-Study Engineers, is the instructor. We hope through this class to develop and train time-study men.

There may be a misconception as to what is a novice, as mentioned by Mr. Haskell. I do not need to run a sewing-machine for a long time to be able to time-study a girl running one. I do not even need to know how to run one. It may be splendid to have a mechanic make the time-study, but a trained observer who knows little about mechanics will get farther and take a better time-study than the man who is a mechanic but is not a trained observer.

Time-Study Affects Machine-Tool Design

Mr. Haskell:—I should like to answer Mr. Mottashed on the "novice." He says, in effect, that he does not know anything about laying an egg, but he can time the laying of an egg.

Mr. Mottashed:—I know more about an egg than any hen that ever lived.

Mr. Haskell:—I do not believe we can gainsay that, but I will say this: If Mr. Mottashed's time-study engineers are not preceded by some first-class mechanics, who line up the job and put the machinery in first-class working order, they are likely to get a good trimming unless they know something about the job.

Chairman Guy Hubbard[11]:—Time-study, disguised under various other names such as synchronization, integration of operations or "simulation," enters vitally into machine-tool design. Elimination of so-called "idle time" due to indexing, backing out of tools, loading and removing of work, and so forth, is accomplished by time-study work on the part of those engineers who lay out the original designs of production machine-tools. These engineers probably carry out their work unconscious of the fact that they are involved in time-study. Their work in this drection is, nevertheless, of almost inestimable importance to the metal-working industries, because upon it depends the basic efficiency of all production machine-tools over the entire useful life of the tools. It is a self-evident fact that no plant can be more efficient as a whole than the average efficiency of its production equipment.

J. B. Armitage[12]:—The machine-tool man gets into trouble because of the time-study men no matter which way he takes them. If the time-study man estimates that it takes a certain time for a job, and the fixture we design for that estimate does not give the production when we deliver the machine, we are in trouble. We have to make it turn out as many pieces as we said it would turn out. If, however, as sometimes happens, it turns out a few more, and five or six duplicate machines are on the order, one gets cancelled.

[10] See S.A.E. Journal, December, 1928, p. 629.
[11] M.S.A.E.—Advertising manager, National Acme Co., Cleveland.
[12] M.S.A.E.—Chief engineer, Kearney & Trecker Co., Milwaukee.

Motor-Vehicle Production in 1928

Figures compiled by the National Automobile Chamber of Commerce, published in *Manufacturers Record* for January 10, indicate a total production of 4,630,000 motor-vehicles in 1928, compared with a production of 3,530,000 in 1927, and 4,480,000 in 1926. The wholesale value of motor-vehicles was $3,045,820,000 in 1928, $2,556,750,000 in 1927, and $3,056,950,000 in 1926. The United States is said to have 78 per cent of the world's automobiles.

Closed cars are said to have comprised 85 per cent of passenger cars manufactured, as compared with 80 per cent in 1927, and 74 per cent in 1926. Seven additional steam railroads reported using buses in 1928, bringing the total number to 67 railroads using 1250 buses. Motor-trucks were reported used as part of their shipping service by 59 railroads. Only 365 street-railways reported using buses in 1928, compared with 370 in 1927, but 1400 more buses were engaged in this service, bringing the total to 9900.

Tires, parts and accessories produced in 1928 are claimed to bring the wholesale value of the main products of the motor-vehicle industry to over $4,665,000,000 for the year. About 4,110,000 people were reported employed in the automobile industry or allied lines, compared with 3,657,000 so employed in 1927.

The large part played by the automobile industry in the industrial structure of the Country is indicated by its reported use of 85 per cent of all rubber imported and consumption of 60 per cent of the plate glass produced, 12 per cent of the copper and 15 per cent of the iron and steel turned out in the United States. Besides the large quantities of cotton and cotton fabrics used in constructing and finishing motor-vehicles, 299,500,000 lb. is said to have been used in 1928 making tires alone. It is stated that 10,860,000,000 gal. of gasoline and 434,000,000 gal. of lubricating oil was consumed by motor-vehicles, and that about 3,600,000 carloads of automobile freight were shipped over the Country's railroads in 1928. It is reported the motor-vehicle retail business in the United States comprises 53,700 automobile and truck dealers, 51,600 public garages, 95,400 service-stations, and 79,100 supply stores. Motor-vehicle taxes last year are said to have totaled $785,386,000. *—Domestic Commerce.*

Profitable Motorcoach Operation

By R. N. GRAHAM[1] METROPOLITAN SECTION PAPER

CONSIDERATION is given by the author to possibilities of radical changes in design of the motorcoach to meet the increasing demands of transportation, and he outlines and analyzes the practices of the company he represents in connection with the operation and maintenance of a fleet of 57 motorcoaches, all of the same make, which supplement the street-railway system in Youngstown, Ohio.

The tendency toward a narrowed field for public-transportation service because of the increasing use of the private automobile is discussed and, in the author's opinion, the urban transportation-company will find the field for the motorcoach and the field for the street-car; but he states that the total use of the combined agencies will be far less than would be the case if the conditions of 10 years ago still prevailed. Further, he asserts that the reduction in the number of potential passengers for a public-transportation line, caused by the use of private automobiles, is a fundamental fact that must be faced by the public-transportation companies. To maintain a profit, there must be less, not more, service by the public-transportation company per unit of population, in his opinion.

The test of the use to be made of motorcoaches and street-cars is on the basis of operating cost per passenger carried, according to the author, dismissing from consideration any idea that the one form of conveyance is more attractive to passengers than the other. This opinion is based upon close observation and a detailed study of the preference of passengers in Youngstown, where 60 per cent of the service mileage is given by street railway and 40 per cent by motorcoach.

In considering the total cost of operation, the author assumes two groups of expenses, Group (1) consisting of all expenses common to street-cars and motorcoaches, and Group (2) all expenses that are inherent in street-cars alone. He then analyzes this classification and also treats the subject of limitations which tend to prevent the substitution of motorcoaches for street-cars.

HARDLY a city-transportation company exists that does not make use of the motorcoach, the manufacturers of which early found that their largest customers for the new vehicle were the established street-car companies. The motorcoach, when adopted as a vehicle for regular city passenger-transportation, presents some marked advantages. It loads at the curb, thus avoiding discomfort and injury to passengers who are compelled to go to the center of the street to board the street-car; it frees the company from dependence upon rigidly fixed routes enforced by heavy investment in tracks and track foundations; and it permits the operation of flexible and easily changed schedules that are fully responsive to changes or even whims on the part of the riding public. But the motorcoach has been handicapped as a vehicle of mass transportation on account of its small size, its higher costs for maintenance and for power per mile, and its much higher rate of depreciation as compared with the street-car.

RADICAL DESIGN-CHANGES SUGGESTED

Because the motorcoach presents operating advantages which cannot be denied, the natural process of development is to ameliorate or remove the disadvantages it presents. The first motorcoach naturally followed the conventional lines of the automobile, but it is not an inherent requirement of the motorcoach that these lines should be followed. There is no operating reason why a large portion of the wheelbase of the vehicle should be occupied by the engine, because an engine located in some other part of the vehicle probably can be serviced better. It is a natural development to use the entire wheelbase of the vehicle for revenue-producing purposes, just as the entire wheelbase of the street-car is utilized. Such design increases the useful size of the vehicle and thus enlarges the radius of its profitable activity. It follows that, if it is no longer necessary to consider the engine as being fixed by the laws of design in the front of the vehicle and driving to the rear wheels through a driveshaft, the engine can be located anywhere in the vehicle in any position if use is made of a generator and motors to convey the power to the wheels. It seems fairly certain that whatever progress has been made along this line will be greatly increased in the future. As a result of such developments, we may find the motorcoach taking equal rank with the street-car in passenger-carrying capacity.

REDUCTION OF DEPRECIATION RATE

As a parallel result of this development, there is no reason why the excessive cost of the motorcoach in the charge for depreciation should not be reduced to a figure equally comparable with that for street-railway operation. The body, underframing, wheels, and every element of the vehicle apart from the engine and tires, can be constructed as sturdily as can the parts of street-cars. Considering depreciation, the experience of many companies indicates that, even with the conventional type of motorcoach, a useful life can be anticipated far beyond that which has heretofore been regarded as good practice. We find that the motorcoaches we purchased in 1922 and 1923, which have been fully depreciated on a five-year basis, are still entirely satisfactory for service and probably can furnish useful service for years.

It was formerly a common belief among those studying motorcoach operation that maintenance costs were bound to pyramid with the increasing age of motorcoach fleets. It costs more to maintain an old vehicle than one fresh from the factory, but in street-railway operation, after a year or two of service with a new vehicle, it is customary to find operating cost reaching

[1] Manager of railways, Penn-Ohio System, Youngstown, Ohio.

a level from which it does not greatly recede or greatly advance in succeeding years.

Operation of the Youngstown Fleet

We operate seven motorcoach routes, the mileage of the vehicles being more than 2,000,000 miles per year for the last several years. Our present fleet consists of 57 motorcoaches, all of the same make. Vehicles have been added from year to year, but none have been purchased since 1926; and the fleet, as a whole, is fairly well aged. Our operating expenses for the last three years, as shown in Table 1, therefore should reflect what can be expected with an old fleet.

TABLE 1—FLEET-OPERATING COSTS IN YOUNGSTOWN, OHIO

	Year		
Total Operating-Cost per Mile	1926, Cents	1927, Cents	1928, (10 Mo.), Cents
Including Depreciation	29.20	30.71	29.35
Excluding Damage Costs and Including Depreciation	26.88	26.75	25.60
Excluding Damage Costs and Depreciation	23.96	23.21	23.31

From the viewpoint of the costs shown in Table 1, it is apparent that, in the case of our comparatively seasoned fleet, there is no pyramiding of costs and that not only the present but future expenses for motorcoach operation can be calculated as readily and as accurately as can those for street-car operation. It is therefore safe to say that the motorcoach is a medium for transportation that can be used in its present conventional form by any urban transportation-company and that, in all probability, considering the very rapid developments that have been made and are being made in design, it can be used to even better advantage in the future.

Tendency Toward Narrowed Field

It does not follow, however, from the foregoing statements that it is sound economic practice in any given community to maintain present street-car operation and immediately find an opportunity to use the motorcoach. In fact, the increasing use of the private automobile has substantially narrowed the opportunity for public transportation. The urban transportation-company will find the field for the motorcoach and the field for the street-car; but the total use of the combined agencies will be far less than would have been the case if the conditions of 10 years ago still prevailed. Then, for all distances above that easily practicable by walking, the dependence of nearly all inhabitants for carriage to and from their homes for work, pleasure or business, was the street-car. At present, a very large proportion of the families formerly so dependent upon public methods of transportation are supplied with private automobiles. Although the use of the private automobile by these families has not eliminated the need for public-transportation agencies, it has altered the characteristics demanded of such agencies.

In the case of any individual family, even though it may be provided with two or three automobiles, there are times when some member of the family must ride in a public vehicle; but the total number of rides by members of each family in public-transport vehicles is less than before the automobile came into common use. Formerly, the population along any given transportation line could be considered as dependent upon that line for conveyance. As the use of the automobile increased, the ratio of rides for each member of the population so served by a given line decreased, so that the net effect as far as the transportation line is concerned is a decreased number of potential customers. A line 2 miles in length in existence 10 years ago might have had a certain headway, but the same line today, while still necessary, may support a headway only one-half as great. Ten years from today the need for public transportation may still exist on such a line, but at that time it may support a headway only one-half as great as at present.

This decrease in number of potential passengers is a fundamental fact that must be faced by the public-transportation companies. The extent to which it obtains varies in different parts of the Country. It is much less marked in the compactly built eastern cities than in the Middle West, Southwest and Far West, where the tendency is toward single homes with yards around them and a garage for every home.

Economics Determines Type of Vehicle

To maintain a profit there must be less service, not more, by the public-transportation company per unit of population. There is, therefore, no economic basis for maintaining a street-car service and supplementing it with a motorcoach service. As the use of public-transportation facilities decreases, there is no economic warrant for the increase of public-transportation facilities. There must be coordination. Where the motorcoach is the better economic vehicle to use, transportation should be provided by it, and by it alone. Where the street-car is the more economical vehicle, there should be no parallel service by motorcoach. Therefore, intensive study should be given to the question of which vehicle best meets the conditions.

I assume that the test of the use to be made of motorcoaches and street-cars is on the basis of operating costs per passenger carried, dismissing from consideration any idea that the one form of conveyance is more attractive to passengers than the other, although I know that many believe the latter consideration cannot be dismissed. My opinion is based upon close observation and a detailed study of the preference of passengers in Youngstown, where 60 per cent of our service is street railway and 40 per cent motorcoach.

It should be almost self-evident that the mere use of the motorcoach will not bring back riders to the public-transportation company. The decreased number of riders is not because of the shortcomings of the transportation company but on account of the inherent advantage of the private automobile, which, to the individual rider, far outweighs any effort by any transportation company, no matter how well it is managed, to overcome. The use of the private automobile for individual transportation is Nation-wide. Where the effort has been made to increase public-transportation service substantially in the face of the steadily lessening use of such facilities, it has been necessary to resort to higher fares, and this in turn tends to accelerate the process of reduction in the number of riders. Where to use the motorcoach and where to use the street-car must be decided on the basis of economic considerations alone. Almost as a matter of principle it must be decided not to use them together on any

given route unless under the most unusual circumstances.

Total Cost of Operation

In determining the cost of operation of the transportation vehicle, we have what are ordinarily known as direct operating-expenses, depreciation, interest on the investment and taxes. Direct operating-expenses comprise maintenance of way and structures, maintenance of equipment, power, transportation and traffic, general, and miscellaneous.

For purposes of comparison, I shall assume a classification that does not exist but which easily can be built up, as follows:

Group (1)
- (*a*) Maintenance of Equipment
- (*b*) Power
- (*c*) Transportation and Traffic
- (*d*) Interest on Investment, including Equipment
- (*e*) General and Miscellaneous
- (*f*) Depreciation on Equipment
- (*g*) Taxes, other than Taxes on Way and Structures

Group (2)
- (*a*) Maintenance of Way and Structures
- (*b*) Interest on Investment, including Way and Structures
- (*c*) Depreciation on Way and Structures
- (*d*) Taxes on Way and Structures

I have inserted in Group (1) all of the expenses that are common to street-cars and motorcoaches, and in Group (2) all expenses that are inherent in street-cars alone. Examining Group (1), I believe it will be the testimony of all street-railway operators who have had any length of experience in the operation of both motorcoaches and street-cars that the cost per mile of any motorcoach large enough to be a factor in urban traffic, if properly operated and maintained, is greater than the corresponding cost per street-car mile. Manifestly, with one-man operation, transportation expense, as represented by wages of operators, will be the same; the inspection expense of motorcoaches will be greater, as will also the expense of maintenance of equipment; and the expense of power, as represented by gasoline when compared with electric power, will be approximately equal. Where there is a tax on gasoline, the expense of taxes on equipment will be greater. There is no reason for any difference in (*e*), the general and miscellaneous item; but, offsetting this fact, we have in Group (2) expenses that are not shared at all by motorcoaches.

Before considering the effect of these expense items upon transportation, we must take into consideration the further facts that the conventional motorcoach for which we have available operating costs over a period of years seats only 29 passengers; that the conventional one-man-operated street-car seats 44 passengers; that the loaded capacity of the motorcoach is never in excess of 50 passengers; and that, in any condition of peak-load traffic, the street-car can carry 100 passengers.

Analysis of Classification

The Group (1) costs of the motorcoach are greater than the Group (1) costs of the street-car. The Group (2) costs of the street-car are not dependent upon the number of cars operated upon a line but are fixed at the time the line is built, the only variation being the very small variation produced in (*a*). Therefore, every additional car-mile operated on any given line decreases the unit cost of the Group (2) expense per mile. Hence, the Group (1) expense being heavier for the motorcoach than for the street-car, it is evident that—on existing transportation routes with headways of 2 to 5 min., or in some cases even 10 min.—the Group (2) expense per mile becomes so small as not to equal the differential in Group (1) expense between the motorcoach and the street-car.

A decade ago there were street-railway routes 1½ or 2 miles in length in the average city that supported fairly frequent headways. Every such route should be given the closest scrutiny when need for rebuilding arises because, in many cases, it will be found that present headways on such short lines, on account of the use of the automobile, are fixed not by traffic demands, but by the minimum headways felt necessary to preserve any sort of convenience. On such lines, the number of car-miles is so small that the Group (2) expense will be high enough to make the motorcoach the more economic unit.

Existing street-car lines between two and three miles in length on which conditions do not warrant extensions constitute a debatable point, when need for rebuilding arises, as to whether motorcoach or street-railway operation is the more economical. When a demand for a new line exists which must be fulfilled, in almost every case short of this three-mile limit it will be found that the present motorcoach is the more economical vehicle.

A careful analysis of present street-car operation will indicate that in almost every case in which a line is operated for a distance of more than three miles with the standard Birney car, the operation is unprofitable. If the headway of the Birney car is fixed by traffic demands at an interval of less than 10 min., the operation of the line will be rendered more profitable by the substitution of larger equipment at a longer interval. If the headway on such a line is fixed, not by traffic demands, but at an interval of 10 min. or more, the same being considered the minimum interval to attract traffic, in all probability the substitution of larger equipment at very long spaces would produce a reduction in the number of riders. Therefore, for lines more than three miles in length where operation can be rendered profitable by the substitution of larger equipment, the motorcoach cannot be a substitute for the street-car under present conditions. However, if the line shows best results with Birney cars operating at long intervals, then, while the line is unprofitable, no more unfavorable results would be shown by operating motorcoaches.

Reducing the foregoing involved considerations to a simple statement, I believe that, with the present conventional motorcoach, it is a grave question whether the substitution of motorcoaches should not be made for street-cars on every short line that it is necessary to operate, and that the necessity for the substitution should be given the closest consideration when need for rebuilding such a street-railway line arises. Further, in the case of all extensions where the line has not been established as a public-transportation route but must pioneer growth and development, such extensions, in almost every instance, can best be given by motorcoach. This is particularly true if the idea is kept in mind that, when traffic becomes so heavy on such long lines as not to be given economically by the present motorcoach, the motorcoach design and

operation at that time probably will have been improved so that an automotive vehicle will be available which will be the complete equivalent of the street-car.

Limitation on Substituting Motorcoaches

On well-developed urban street-car routes such as constitute the backbone of the transportation system in our larger cities, such routes being double-tracked, several miles in length and operating on frequent headways, the motorcoach cannot at present be substituted. The use of motorcoaches to parallel such routes can be excused only if superior service is given by the motorcoach on account of some inherent defect in the operation of the street-car routes. Real advancement can be made in transportation operation only by removing the conditions that interfere with giving good service, not by resorting to the use of motorcoaches and thus duplicating expense. This is true as a fundamental statement whether the parallel competing service is given by the same company that owns the street-car lines or by another company; the unfortunate fact would be the same in both instances.

A great deal of attention has been attracted by the operation of motorcoach lines supplementing street-railway service at a higher rate of fare. The higher rate of fare enlarges the radius of profitable operation of the motorcoach. In viewing such experiments, let us not lose sight of the fact that the number of customers for public transportation in any given built-up area has been greatly decreased and not increased within recent years. On this account, is it not a desperate measure to provide duplicate service for a reduced market? Should not the effort be made to remove the obstacles to street-car service that render it inferior to the duplicate motorcoach-service? Where there is a chance to remove such obstacles and actually make a profit from the express motorcoach-service, there is no reason why the transportation company should not operate such a service; but the fact that there is demand for such service should inevitably focus determined effort to build up the quality of the street-car service.

Summary

Let us assume now that you, who are considering fitting the motorcoach to the transportation needs, have in your control the subject of furnishing the vehicle for mass transportation in your city, which we will call Utopia. You have in existence certain street-railway routes. Some of these routes, in all probability, can be superseded immediately by the motorcoach with advantage to yourself and to the public. On probably the greater part of your existing routes you might improve the service to some extent by operating motorcoaches, but without profit to yourself and, therefore, your ability to give service on the entire system would be crippled. On these routes you must not undertake to furnish more service to a decreasing number of patrons but must attempt to improve the service that you give, if possible making it comparable with the service that could be given by using coaches.

As your city grows you will find it necessary to lay out new lines. These lines should be operated with motorcoaches, having two thoughts in mind: first, that such routes can be installed by operating motorcoaches for much less capital expenditure than is required for street-cars; and, second, that by the time when it may become necessary to extend street-railway lines to such developments, the motorcoach may be more suitably equipped to do the work, from the viewpoints of physical capacity and of operating cost, than the street-car does it today.

Prospects of Automobile Industry in 1929

PRESENT prospects in the automobile industry are for an output of from 5,000,000 to 5,400,000 cars and trucks in 1929, according to the Union Trust Co., Cleveland. This outlook is based upon favorable indications from three main sources of motor-car buying.

These sources include replacements, new buyers' demand, and exports, says the bank in its magazine, *Trade Winds*. During 1929 the replacement demand for cars will probably be the largest in the history of the industry. This estimate is based upon the fact that there are now approximately 25,000,000 cars in use in this Country and that the average life of a motor-car is estimated at around six years.

During the current year the production of 1923 will be ready for replacement. It will be remembered that 1923, with an output of more than 4,000,000 units, was the first year of gigantic production. A reasonable estimate of replacement demand for 1929 is something more than 3,000,000 cars and trucks.

One of the most amazing and striking trends in the automobile industry has been the rise of export demand. The expansion of world trade and the rise of living standards throughout the civilized world, coincident with the progress in the stabilization of European conditions, are resulting in a great movement looking to the motorizing of many countries.

During 1928 the exports of cars and trucks from this Country approximated 500,000. This figure compared with 78,000 in 1922. Further important increases in foreign demand are expected during 1929.

The degree of new buying demand has interesting possibilities for 1929. Its extent will depend upon the continued spread of general prosperity and upon the rate of increase in the number of families with two cars. Both these factors are closely related. It is estimated that 15 per cent of American families possess two cars each, while in 8 per cent of the families there are three cars each. This condition is growing more pronounced. The single-car garage is becoming extinct in many sections.

In agriculture steady improvement in purchasing power is being made, and there is now a widespread movement toward mechanization of farms, which is stimulating influence upon the demand for motor-cars as well as implements and tractors. Each year many thousands of new surfaced roads are added in the United States, and this is another important factor in creating a new demand for automobiles.

It is estimated by some authorities that despite the large output of 1928, there was an underproduction of cars in the low-price class. All these factors combined point to a possible domestic and export demand for American makes of cars that may exceed 5,000,000 in 1929.

Desirability of a Large-Bore Engine

By Alex Taub[1]

Annual Meeting Paper — *Illustrated with* Drawings

COMPARISONS are made of the respective characteristics of the large-bore short-stroke engine and the small-bore long-stroke engine in connection with the argument of the author that the former engine best fulfills the requirement that an engine must be a good product that is easily produced. He chooses the L-head type of engine for purposes of illustration, since this type is within the scope of the experience of all automotive engineers.

When consideration is being given the specifications of a new engine, the first problem to be met is the determination of length. Usually a certain length is set arbitrarily, but this circumscribes the designer at the outset and, for some unaccountable reason, a new project is thus compromised rather than to change the preconceived idea of what the length of wheelbase must be. But there is abundant evidence in the industry as to what happens when a designer starts to "crowd," and the author asserts that, if engines are to represent something more than so much cast iron equipped with plumbing, sufficient space for the engine—at least enough to permit proper consideration for each function—must be allowed. He states also that the large-bore short-stroke engine demands elbow room for itself and its parts, and then discusses how large the cylinder bore should be.

After considering the subjects of valve cooling and engine stability, cylinder-block construction is analyzed and a method of construction is described whereby the block is cast on end. By this method each half of the block is a separate casting but a simple liquid assembly of the two is made by fastening together the two molds in their respective flasks before pouring.

The advantages and disadvantages of the two types of crankshaft are discussed, as is also the proper distribution of crankshaft material to secure correct balancing; and the effects of counterweights are analyzed.

In conclusion, the author says that the large-bore design offers a good engine that has a maximum performance over the longest period, and that can be produced most easily and at lower cost. It has also better cylinder-blocks, better crankshafts for less cost, and presents a greater opportunity for further development than does the small-bore long-stroke engine.

It is stated by one discusser that, to get water close to the exhaust-valve seat, valve ports are often crowded so that it becomes necessary to make a D-shaped port, and that this is not as satisfactory with regard to the seat itself remaining perfectly round under operating conditions as is the concentric type of port. Other critical analyses, with diagrams, are submitted in relation to bore-stroke considerations, one conclusion reached being that an increase in bore-stroke ratio for engines of the same power increases the bearing pressures. Crankshaft stiffness and weight considerations, as well as the advantages of the short-stroke engine, are treated also.

Engine smoothness and factors that limit engine length are discussed, and the relative detonation tendencies of the small-bore and the large-bore engine are considered.

THE principles herein expounded are based upon the foundation that, to be satisfactory, an engine must represent a true picture of maximum utility per dollar to both user and manufacturer. For the user, it must be capable of generating horsepower over the greatest period of time for the minimum upkeep and with minimum physical disturbance. For the manufacturer, it must be capable of being produced to satisfy under maximum-volume operation, and must have maximum inherent facility for foundry, machine-shop and assembly, as well as for being a good product. A slogan that expresses these requirements might well be: "A product easy to build good"; and I shall endeavor to prove that the large-bore short-stroke engine best fulfils this idea. Since the L-head or side-valve type of engine is within the scope of the experience of all automotive engineers, I shall confine my remarks to it.

Much has been said about the increase in efficiency available to us by the use of a small bore and a long stroke as compared with a large bore and short stroke, owing in the main to the low surface-to-volume ratio and hence to lower heat-loss of the more compact unit and its resultant greater percentage of useful work. This sounds well, but it will hardly stand up against present knowledge of combustion-chamber architecture, which is definitely pointing to non-compact combustion-chambers for smoothness and a high surface-to-volume ratio for a portion of the burn as an aid in preventing detonation. The large-bore job provides a naturally broad chamber which lends itself readily to manipulation for the purpose of combustion control. It is my opinion that the large-bore short-stroke engine, as a principle of construction, represents the simplest and most economical method of obtaining a product that is "easiest built good"; and of all the advantages both advertised and real, this is the most important to us, because we are all striving to build products that are good, and the product that is easiest built good will most often be good.

Engine Fundamentals and Wheelbase

When consideration is being given to specifications of a new engine, the first ground rule to be met is that of length. Usually we are given or we arbitrarily set just so many inches and fractions thereof for the job. Thus we are circumscribed at the outset and for some unaccountable reason we cheerfully consider compromising a new project rather than change our notion of what the wheelbase must be.

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Compare the relative importance of wheelbase, as to whether it should be 110 or 111, or 115 or 116 in., with the fundamentals of engine design. Try to think of wheelbase as important and consider the fact that one of the greatest producers of cars during last year increased the wheelbase 4 in. to fit an artist's conception of how long the hood should be for correct appearance. History proves this move to have been sound. If it was sound to concede 4 in. for appearance, are we not entitled to half that much for engine fundamentals? Yet, recently, a prominent radiator engineer was discussing cooling problems with an equally prominent engineer of a motor-truck and motorcoach company. The man interested in cooling requested 1 in. of additional space between engine and radiator to allow for additional belt and fan on a large motorcoach, but its engineer turned down the request on the ground that the wheelbase, which was 260 in., would be increased to 261 in.

There is abundant evidence in the industry, as represented by its products, as to what happens when we start to "crowd." If our engines are to represent something more than so much cast iron equipped with plumbing, we must have sufficient space for the engine; at least enough to permit proper consideration for each function. The large-bore engine is arbitrary; it demands elbow room for itself and its parts. But how large should the bore be? It is much easier to say how small it should be, and this I shall endeavor to do.

Determining Bore-Size

Consider for a moment that we are about to design a new engine. It is assumed that we know the purpose, type of performance and range desired, and therefore the piston displacement. Much can be written about piston displacement or, rather, the lack of sufficient piston displacement. However, let us assume that this matter has been settled; then, if we are to have valves in the engine, the valve size should be our initial consideration. Bearing in mind that we want the easiest engine to build good, we should select a valve-lift that will call for a camshaft which incorporates a profile that will not burden the shop; in other words, a short lift with the diameter of the valves leaning toward the large size. With the valve diameter set, we can lay out what should be the minimum engine-length between bearings, allowing the proper amounts of metal and water between each two valves. The water space must be sufficient to permit the foundry to produce it at minimum cost and with maximum assurance that we shall get what we require. A definite space is thus determined, and the largest bore in the desired multiple required that can be placed therein with due allowance for walls and water space will represent the minimum bore to be used. In my opinion, this bore will prove to be the most practical and most economical. From the bore, the crankpin size can be determined. The sizes of the main bearing and the cheeks of the crankshaft should be ascertained from the range and performance desired. In this way the proper length of the engine can be decided by sound practice.

Valve Cooling

When an engine is small bored and an effort is made to take advantage of this fact to shorten the powerplant, the decision inevitably is made to dispense with water between the exhaust and the inlet-valve ports. This decision has been made many times in our history and the result has always been unsatisfactory, if we admit that it is undesirable to have the product fail to maintain its performance after reasonable hard driving. By this is not meant small normal losses caused by a higher operating-temperature, but a distinct flatness. It is unsatisfactory also if we believe it undesirable when the products require frequent valve-grinding and valve replacement and when the engine-block seats indicate warpage.

There was a time when the use of cooling water between the cylinder-bores was regarded as a luxury to be employed only in the higher-priced machines. The builders of medium-price and low-price cars felt that they had done well if they allowed more than a single wall-thickness in solid metal between bores. This practice has been abandoned and I am sure it will not be revived. Its attendant evils have been eliminated. Then why should we continue this evil practice and apply it to the most sensitive portion of the mechanism, the valve and its seat?

Engine Stability

Fig. 1 incorporates two sections through engine blocks. The comparison is odious. One is a section through the valve ports of a 2 11/16 x 4½-in. engine; the other is a similar section of a 3⅛ x 3⅜-in. job. The capacity of each engine is 154 cu. in. I am fully entitled

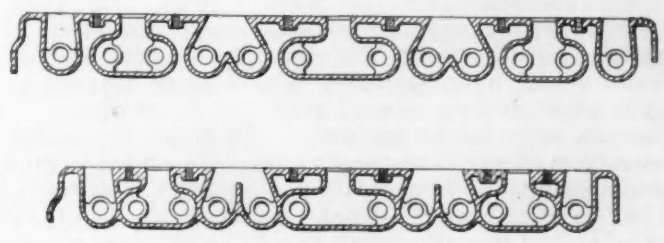


Fig. 1—Comparative Cross-Sections Through Two Engine Blocks

The Capacity of Each Engine Is 154 Cu. In. The Section Is Taken Through the Valve Ports, the Bore and Stroke of One Engine Being 2 11/16 x 4½ In. and, of the Other, 3⅛ x 3⅜ In.

to make this comparison, having designed both jobs. The large-bore engine was designed to meet the specifications of H. M. Crane; the small-bore engine, to meet my own specifications. The engines were built as part of a program to determine what constitutes proper bore and stroke. The greater efficiency of the small-bore engines never materialized. At no time did the small-bore engines ever perform as well as the large-bore engines because they never stayed in tune. The large-bore engines always set the pace.

It was during this program that we found that fundamental information on combustion-chambers was sadly lacking. We decided to step-up the compression of the small-bore engine to a point at which detonation would be the limiting factor. We quickly discovered that thump or roughness was the real obstacle, and that detonation was not. It was noticeable at the time that the small-bore engine thumped more than did the large-bore engine. This was unexplainable at that time, although the explanation is easy enough now.

A cylinder-head-development program was started. We had to use the large-bore engine on the dynamometer because it was the only engine with which we could make check runs. We ran this engine every day

for six months, and learned something about engine stability and durability that I am sure our crew never will forget. While this program was in progress we were constantly applying first aid for the other engines.

What was gained by the small-bore engine? It was 15 lb. lighter and 1 13/16 in. shorter; that was all. It had no cooling water between the cylinder-bores, and that compromised the valve-seats. The result was a poor engine.

Cylinder-Block Construction

Fig. 2 is a comparison of two engines that were being produced last year. One is a $2\frac{7}{8}$ x $4\frac{3}{4}$-in. and the other a $3\frac{1}{4}$ x $3\frac{3}{4}$-in. engine. Each had a capacity of 186 cu. in. A comparison of the coring around the valve port is interesting. Both blocks were purchased from the same foundry. The small-bore engine gave a great deal of trouble. The large-bore engine is still running; it was and is today the show job of that foundry. Its cooling efficiency is so much greater that it is hardly fair to make a comparison between the two engines. In the large-bore engine we were able to have an opening at both ends of the engine block and make a visual inspection. We therefore provided a design that could be easily cast and easily checked. The foregoing small-bore-engine block weighed 40 lb. more than that of the large-bore engine. I was more or less responsible for the proportions of both engines.

In a further effort to establish basic economies in strict accordance with the slogan "a product easy to build good," we collaborated with a large foundry to determine whether some of the recognized evils of the foundry could be side-stepped by exploiting the natural roominess of the large-bore engine. Here we scored a major gain since, from this, a new principle of cylinder-block molding was developed. For each block, 145 lb. of core sand was eliminated as well as its proportional amount of core ovens, floor space and trucking of cores back and forth. The mold was of green sand except for water-jacket and valve cores and for the pockets over the main bearings. The crankcase construction was, up to that time, believed to be the best bearing-structure available but too costly for use in low-price engines; yet it was available for less cost than the worst design of which we could think.

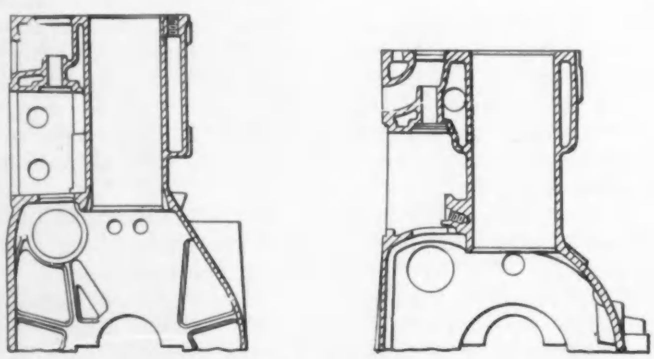


Fig. 2—Comparison of Cylinder-Block Construction

Each Engine Is of 186-Cu. In. Capacity, the Bore and Stroke of One Engine Being $2\frac{7}{8}$ x $4\frac{3}{4}$ In. and, of the Other, $3\frac{1}{4}$ x $3\frac{3}{4}$ In.

Fig. 3 illustrates this general principle of molding. The block is cast on end, the assumption being that each half of the block is a separate casting, each in itself making a simple mold. The two molds in their respective flasks are fastened together, and a simple liquid assembly is thus made of the block. The result is a greater uniformity of castings on account of the accuracy of green-sand handling and minimum core shift,

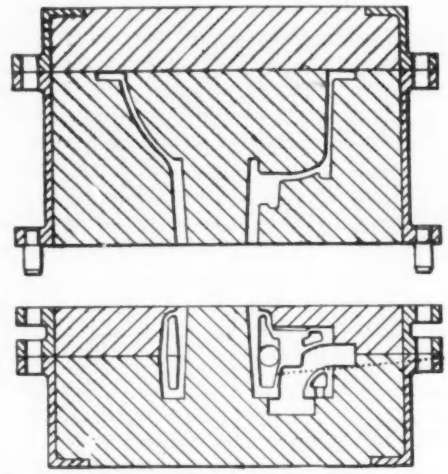


Fig. 3—Method of Cylinder-Block Molding

The Block Is Cast on End, the Assumption Being That Each Half of the Block Is a Separate Casting. Each Is a Simple Mold in Itself. The Two Molds in Their Respective Flasks Are Fastened Together and a Simple Liquid Assembly Is Thus Made of the Block

improved construction for bearing supports, as shown in Fig. 4, and lower cost because it is easily produced. A real sample of a good product easily produced.

Crankshafts and Distribution of Their Material

Considering crankshafts in connection with short-stroke versus long-stroke engines, it is difficult to find a single point that might place the long-stroke-engine crankshaft in a favorable light. The advantages seem to be entirely with the short-stroke engine. Continuing the previous comparison of the $3\frac{1}{4}$ x $3\frac{3}{4}$-in. and the $2\frac{7}{8}$ x $4\frac{3}{4}$-in. engines, the short-stroke-engine crankshaft weighed 13 lb. less than that of the long-stroke engine, yet the crankpin diameter of the latter was $1\frac{7}{8}$ in. and that of the short-stroke engine was 2 in.

Fig. 5 affords a general comparison of both crankshafts. Note that the short-stroke-engine crankpin and the main bearing overlap 3/16 in., but that the long-stroke-engine crankpin includes $\frac{3}{8}$ in. of unsupported cheek. Getting down to the fundamentals of distribution of material, we might say that an ideal crankshaft is one that incorporates the maximum stiffness, highest vibration-period position, and minimum duration of vibration period for the minimum number of pounds of steel.

An investigation was made some time ago to determine the effect of metal distribution on the crankshaft from the viewpoint of vibration periods. A crankshaft was designed and made that contained the minimum amount of steel. It was found to be too light and the problem then was to make the maximum improvement for the minimum of steel added. A combination of crankshaft designs was made and $\frac{1}{8}$ in. was added to the diameters of the main bearings and crankpins, and to the thickness of the crank cheeks. This material was

added at each position separately to determine the effect. The results were as follows: The addition to the main bearing raised the period position by 75 r.p.m., which was a negligible gain; and that to the crankpin by 500 r.p.m., which was a real gain. Adding to the crank-cheek thickness decreased the duration of period by 50 per cent.

These results afford food for thought, as the general practice today is to make the crankpin diameter considerably smaller than that of the main bearing. The addition to crank-cheek thickness produced

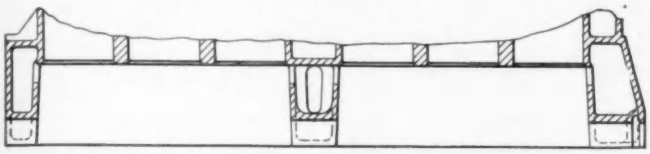


FIG. 4—DESIGN SHOWING IMPROVED CONSTRUCTION FOR BEARING SUPPORTS

no change in position of the period, but it served to decrease the duration of the period by 50 per cent, which is a most important gain that is deserving of much more than passing consideration. Any attempt to gain length of bearing by making the crank cheeks thinner, though wider, is a practice that should be considered well before being carried through.

Although interesting, the foregoing data relate to the judicious addition of material, and we were therefore stimulated to an attempt to gain period advantages by removing material. Hence, a check was made on a crankshaft having its stroke shortened 1/4 in. while the original dimensions of the main bearing, crankpin and crank cheeks were maintained. The result was a 300-r.p.m.-higher position of the period and 30 per cent less duration. Thus a gain was made by using less material. If we decide to remove more material from the crank cheeks by shortening the stroke in its relation to the crankpin diameter or to the cheek thickness, we can make a further gain in either position or duration of period. It is therefore obvious that the short-stroke-engine crankshaft inherently incorporates definite advantages with regard to periods.

Effects of Counterweights

Considering the short and the long-throw crankshafts from the viewpoint of counterweights, it is obvious that the weight to be offset is centered mainly about the crankpin and hence that the dynamic out-of-balance produced is proportional to the stroke. Then it is plain that the need for counterweights to offset bearing loads is far less in the short-stroke than in the long-stroke engine; therefore, the short-throw crankshaft has the advantage, so far as counterweights are concerned. On account of the general compactness of the short-throw crankshaft, it is a much easier product to produce in the forge shop, particularly if counterweights are desired and are forged integrally.

During its progress through the shop, the inherent stiffness of the short-throw crankshaft enables rapid and accurate handling through its machining and grinding processes. Further, balancing a given amount of material that is out-of-balance is less disturbing to the short-throw than to the long-throw crankshafts.

In this discussion I have considered large-bore and small-bore engines of equal piston-displacement; therefore, comparisons are to be made at equal speeds and power and the reciprocating parts can be directly compared by weight and also geometrically. The weight of the piston and connecting-rod of the small-bore engine is less than in the case of the large-bore engine, even though the rod is longer for the smaller bore for equal stroke-to-rod ratio.

In this connection, it is well to call attention to the fact that the small-bore-engine connecting-rod cannot be withdrawn through the top of the engine and hence the addition to the crankcase height necessitated by a long connecting-rod is needed to permit the removal of the piston from the bottom. With the large-bore engine the connecting-rod can be withdrawn from the top; therefore, full advantage of the short connecting-rod can be taken.

Loading

Weight is in favor of the long-stroke small-bore engine by approximately 35 per cent. However, the short stroke partly offsets the resultant inertia loading, leaving a 9-per cent increase compared with the large-bore; but, since the centrifugal loading of the crankpin is also to be considered, and in our particular comparison it is 22 per cent greater for the small-bore than for the large-bore engine, it is obvious that the small-bore long-throw crankshaft has a greater load to sustain than has that of the large-bore short-stroke engine. Since torsional loadings and periods are the greatest consideration, the diameter of the crankpin and bearings should be fundamentally the same for both engines, because the power and speed of each are equal.

Attempting to increase the capacity of the connecting-rod bearing of the small-bore engine by increasing the diameter of the crankpin leads naturally to an increase in velocity of the bearing surface; hence, there is very little gain in the pressure-velocity characteristic. But in the large-bore engine, we can increase the length, for which there is usually room, and make a direct gain because the bearing area is increased without increasing the surface velocity.

In summarizing all of the foregoing, it seems that the large-bore engine offers

(1) A good engine easiest produced
(2) Maximum performance over the longest period
(3) Lower cost of production
(4) Better cylinder-blocks
(5) Better crankshaft for less cost
(6) Greater opportunity for further development

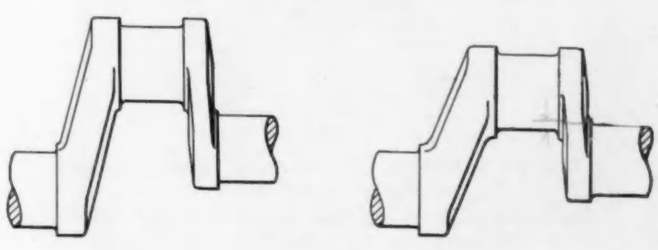


FIG. 5—COMPARISON OF CRANKSHAFTS OF A 3 1/4 x 3 3/4-IN. AND OF A 2 7/8 x 4 3/4-IN. ENGINE

It Should Be Noted That the Short-Stroke-Engine Crankpin and the Main Bearing Overlap 3/16 In., but That the Crankshaft of the Long-Stroke Engine Has 3/8 In. of Unsupported Cheek

All of these factors are necessary to obtain the maximum utility per dollar for the manufacturer and the user.

THE DISCUSSION

L. P. SAUNDERS[2]—Mr. Taub states that "the length of the engine can be set by sound practice." Let us assume that the water-jacket of both the short and the long-stroke engine extends to a position representing the top of the piston when at the bottom of the stroke. We then find that the area of water-jacketed surface per cylinder-bore for the long-stroke engine is 50.3 sq. in. as compared with but 44.1 sq. in. for the short-stroke engine. With a given volume of water per horsepower per minute in circulation through the jackets, the water is changed more times per minute with the large-bore than with the small-bore engine.

Valve ports are often crowded to such an extent that, to get water close to the exhaust-valve seat, it becomes necessary to make a D-shaped port, and this is not as satisfactory with regard to the seat itself remaining perfectly round under operating conditions as is the concentric type of port. This tendency for the valve seats to get out-of-round is one of the major causes of "tired" engines. One of the essentials for present-day engines is to provide sufficient water around the valves, because the performance of an engine may depend on this feature of the design; and the large-bore type assures that the jacket design will be satisfactory.

Another design feature that is assuming more and more importance is the number and location of cylin-

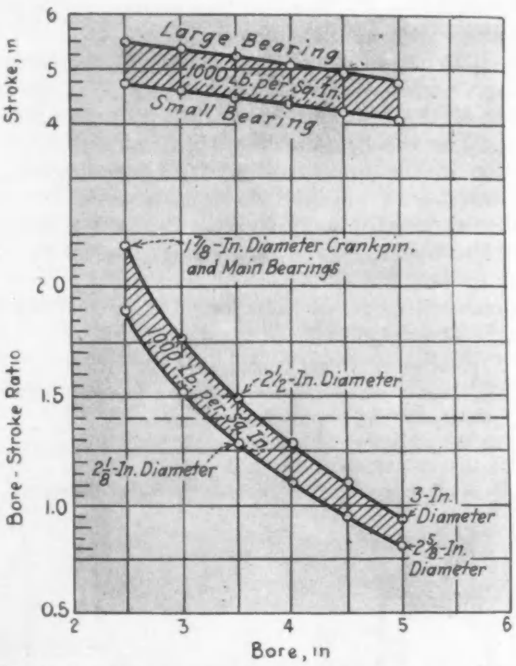


FIG. 6—PLOTS OF STROKE AND BORE-STROKE RATIO AGAINST BORE

Each Diagram Shows Two Lines, the Upper One Representing Large and the Lower One Small-Diameter Bearings

der-head holding-down bolts. With different types of antifreeze solution now on the market, it is imperative that the cylinder-head-and-block joint be maintained. Once again the large-bore engine gains, for there is an abundance of room to place the bolts without interfering with the water flow around and over essential parts of the jackets. Becoming specific and comparing the cooling of the large-bore with that of the small-bore

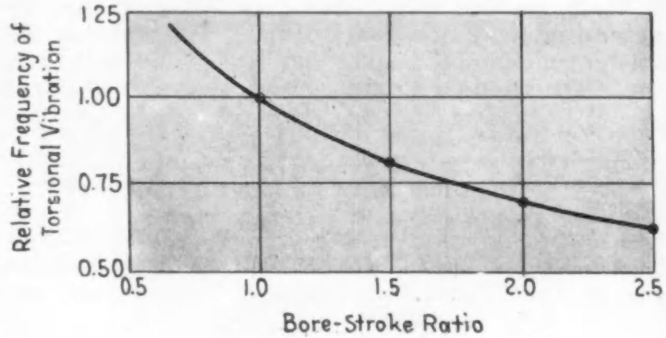


FIG. 7—RELATION BETWEEN TORSIONAL PERIOD AND BORE-STROKE RATIO

The Formula $N = C/\sqrt{R}$ Is Used, Where N Is the Rate of Torsional Vibration, C Is a Constant, and R Is the Bore-Stroke Ratio. The Curve Shows That the Period Speeds Are Increased 30 Per Cent When the Ratio Is Decreased from 1.75 to 1.00

engine illustrated in Fig. 2 of the paper, the radiator for the large-bore engine contained 2 sq. ft. less of material than that for the small-bore engine and, at 50 m.p.h., the large-bore-engined car would operate in an air temperature approximately 15 deg. fahr. higher without boiling than would the small-bore-engined car.

Particular attention is drawn to the method of distributing the water to the exhaust valves. Fig. 2 shows the generous space and the water-discharge duct from the water-pump between the cylinder-barrel and valve ports on the large-bore engine, and the generous amount of water between the valve ports and the top and sides of the block casting, as compared with the small space at this place and the small amount of water between the cylinder-barrel and valve ports on the small-bore engine, this small space eliminating the possibility of a water-distribution duct and necessitating that the water from the pump be discharged into the front end of the block, with attendant poor water-distribution.

Water-jacket design and production, from a foundry viewpoint, have been analyzed and it is evident that all jacket designs today which give trouble are the result of pet ideas of the designers and skimped areas around valve ports. Obviously, the large-bore engine represents the better of the two designs from this viewpoint.

OTHER CRITICAL ANALYSES

A. J. MEYER[3]:—To illustrate his ideas, Mr. Taub has mentioned results obtained on a few engines built especially to decide what is the most desirable ratio between bore and stroke; but I think his comparisons are not entirely fair. Apparently, he has compared a well-designed amply-proportioned short-stroke engine with a long-stroke engine that has been crowded to the limit. In doing so, I believe he has failed to show some of the material advantages that the short-stroke engine possesses.

In my opinion it is possible to build a good substantial engine having high output and durability with

[2] M.S.A.E.—Experimental engineer, Harrison Radiator Corp., Detroit.

[3] M.S.A.E.—Supervisor of design, Continental Motors Corp., Detroit.

either a long or a short stroke. Good examples of both types are on the market. It is not necessary to cast cylinders and valve pockets together for a long-stroke engine. We can decrease the valve size or lengthen the engine until we have a good engine in which the bearing loads are reasonable. Let us not make comparisons until after this has been done.

In my analysis of this subject I have used a series of engines, all of the same type and covering a wide range of displacement, choosing both a long-stroke and a short-stroke engine for each size. The peak horsepower and speed of each engine have been determined by an empirical formula which takes into consideration valve diameter, lift and displacement. This formula has been in use for a long time and gives results that are very close to those of actual tests.

The first conclusion derived from this analysis is that an increase in bore-stroke ratio for engines of the same power increases the bearing pressures. We have gone one step further. Realizing that maximum compactness is a desirable feature, we have laid out these engines as compactly as possible consistent with good cooling and foundry practice. Next we proceeded to find the maximum stroke permissible that will produce a bearing pressure of 1000 lb. per sq. in. on all bearings at peak speed. From this investigation we conclude that the maximum safe bore-stroke ratio varies inversely with the displacement. The results are shown in Fig. 6, where the stroke and also the bore-stroke ratio are plotted against the bore. Each diagram shows two lines, the upper one representing large and the lower one small-diameter bearings.

We see that, from this viewpoint, a much higher bore-stroke ratio can be applied to engines of small displacement. Where large displacements are required, the limiting stroke becomes smaller than the bore; so, either we must cut down on speed and power, or space the cylinders farther apart, or use counterweights. But counterweights are objectionable on high-speed engines from both production and performance viewpoints unless they are held to the minimum size. A slight change in bore-stroke ratio usually will eliminate the necessity for counterweights. Therefore, it seems that the most practical solution is to make the engine longer.

Our analysis shows further that, for example, a 4 x 6-in. engine requires more length than a 4½ x 4¾-in. engine. It is obvious that the latter engine is likely to be much lighter, and it also will have other advantages such as a stiffer crankshaft.

Crankshaft Stiffness

As to the stiffness of crankshafts, our experience agrees with Mr. Taub's that the short-stroke-engine crankshaft is far superior in all respects. But with respect to his experiments concerning metal distribution and its relation to vibration periods, although I do not question the facts, I want to caution against generalizing on his conclusions. It is not always true that stiffening the pins produces more effect than stiffening the main bearings. We have evidence of the opposite results. Where to place the material depends on the stroke, the number of cylinders, the number of bearings and on the relative stiffness of the component parts of the crankshaft. The answer to this question can be obtained readily by mathematical analysis, as has been proved to us by many years of experience on a large number of crankshafts of widely varying size and design.

Concerning the relation between torsional period and bore-stroke ratio, it can be proved that, if the bearings and cheek size are the same, the torsional frequency becomes inversely proportional to the square root of the ratio. This is illustrated in Fig. 7, where it can be seen that the period speeds are increased 30 per cent when the ratio is decreased from 1.75 to 1.00.

Weight Considerations

In the course of our analyses we found several reasons for believing that, in general, a long-stroke engine is likely to be heavier. This also is indicated by Mr. Taub's figures, especially where his long-stroke engines were really undersize. This belief has been substantiated by an investigation of the weight of engines in current production.

Fig. 8 shows the weight per cubic inch of these engines plotted against their bore-stroke ratio. The engines are all of the same make, and the figures indicate their displacements. They were all built for good power combined with good durability, and not for purposes of comparison. Even though they are not all of the same construction, the increase in weight with the related stroke is very apparent. If we apply the results shown by the chart, Fig. 8, to an engine of 200-cu. in. displacement, we find that the engine weighs 600 lb. when the bore-stroke ratio is 1.85 and 430 lb. when the ratio is 1.00, this being a saving of more than 28 per cent. In quantity production, this would result in considerable savings in addition to those which Mr. Taub indicates. For performance and durability, I still favor the 430-lb. engine.

Reconsidering the results, we find that in a short-stroke engine the bearing loads are lower, the weight of the entire engine is less, and the crankshaft is stiffer. Therefore we conclude that the maximum safe

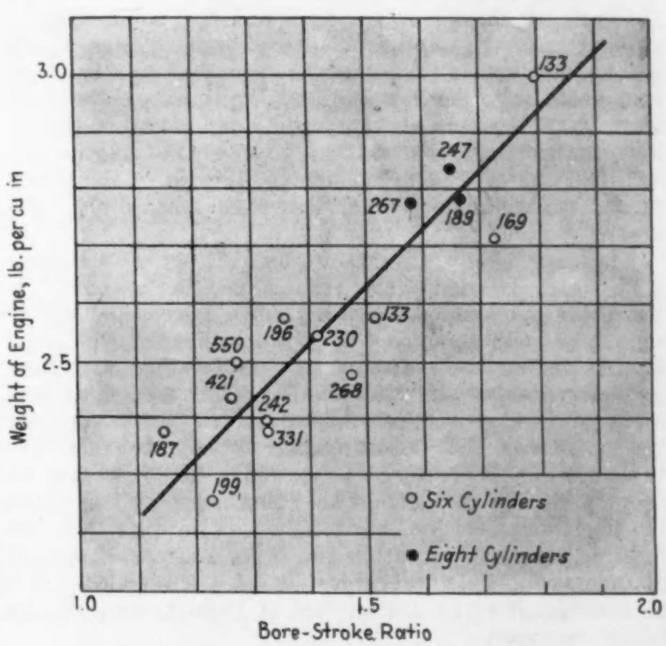


Fig. 8—Weight Per Cubic Inch of Engine Plotted Against Bore-Stroke Ratio

The Engines from Which the Data Were Obtained Were All of the Same Make. The Figures Indicate Engine Displacement in Cubic Inches

power-output per pound of engine weight is substantially higher in a short-stroke engine.

Mr. Taub has emphasized that he thinks it wrong that, for unaccountable reasons, the engine designer is limited at the start. I think that these reasons are not so unaccountable. They may have a slight economic background, but I consider that the main reason is lack of knowledge of the far-reaching influence of our most important design-factor — the bore-stroke ratio—and that it is not generally realized that the man who decides the bore and the stroke that are to be used and insists on compactness is responsible for the quality of the entire engine.

ALEX TAUB:—Mr. Meyers has submitted some interesting comparisons, but it appears from his remarks that I have stated that the small-bore weighs less than the large-bore engine. This is not true. The large-bore engine is always the lighter when equal quality is designed into both large-bore and small-bore engines. However, where utility per dollar is sought and small bore is being considered, the design is usually deliberately crowded.

DR. H. C. DICKINSON[4]:—It is a rather startling fact that 50 to 60 per cent of all the fuel we burn is burned merely to shear an oil-film; that is, to turn the engine over. That has some bearing on the bore-stroke ratio because it is obvious that maximum displacement is obtained in a cylinder which has the same diameter as its length. In other words, decreasing the bore-stroke ratio has a very material effect in reducing the total amount of oil-film that has to be sheared in the operation of the engine.

TORQUE REACTION CONSIDERED

CHAIRMAN L. P. KALB[5]:—Regarding engine smoothness, I do not believe that the flywheel, any more than the resistance at the rear wheels, has much to do with damping out torque reaction. The principal factors that affect it are the stiffness of the frame, the resistance of the front springs, and the polar moment of inertia of the engine. Concerning the typical short-stroke and long-stroke engines described by Mr. Taub and assuming that he and Mr. Meyer are both right, that is, that the weight of the long-stroke engine is no greater than that of the short-stroke engine, we will find that the polar moment of inertia of the short-stroke engine is very much less than that of the long-stroke engine.

The only one of the factors affecting torque reaction which is within the engine designer's control is the polar moment of inertia. If we carry this matter of stroke reduction too far, the final result will be an engine having the center of gravity located practically at the center of the crankshaft. Then the polar moment of inertia will be reduced to the minimum, and the only way that additional resistance to this disturbance can be restored is to add a heavy weight to the top of the cylinder-head. Engineers are fighting the problem of torque reaction just as hard as they are fighting torsional vibration and other sources of engine disturbance. This, therefore, is an item which must be considered when the subject of bore-stroke ratio is being discussed.

[4] M.S.A.E.—Chief, heat and power division, United States Department of Commerce, Bureau of Standards, City of Washington.

[5] M.S.A.E.—Assistant chief engineer, Continental Motors Corp., Detroit.

[6] M.S.A.E.—Chief engineer, Chrysler Motors, Inc., Detroit.

ENGINE-LENGTH LIMITATIONS

H. T. WOOLSON[6]:—The limiting factor governing length in an L-head engine is usually the space required for the valves. Having decided upon a certain displacement, having selected valve sizes of sufficient capacity to take care of this displacement, and after having allowed sufficient space for the center bearing, the length of the engine is established. It then will be possible to use as large a bore as will permit the use of satisfactory water passages, the stroke being calculated so as to obtain the desired displacement. Having determined valve sizes and cylinder-block length, there is no doubt that the largest bore which can be developed satisfactorily within this space, up to a certain limit, will give the most desirable engine.

During my past experience in marine work there was never a thought of designing an engine without completely surrounding every valve with water. In these days, however, there is considerable resistance to adding engine length, which necessitates a longer chassis. The body department naturally desires to use the extra length in the body. It has been a favorite practice to put inlet and exhaust valves fairly close together. This practice is being followed on some of our best cars today.

Mr. Taub's paper deals mainly with small-size engines, and he does not state definitely how far we should go toward reducing bore-stroke ratios. When we have arrived at a maximum bore of say 3½ to 3⅝ in. to get the desired displacement, we must necessarily use a longer stroke. It is believed that satisfactory cooling of the valves with water can be accomplished without increasing the length of the engine unnecessarily.

MR. TAUB:—Although Mr. Woolson agrees with us as to the desirability of having exhaust valves completely surrounded with water, he infers that this is not done on some of the best cars today. It is an interesting fact that some of our so-called "best" cars are among those that have a habit of getting tired when pushed hard.

Mr. Woolson has also set a limit on the bore size somewhere between 3½ and 3⅝ in., yet many cars have been in use with bores of 3⅞ and 4-in. diameter. It should be remembered that we are entering an era of combustion control which certainly will tend to remove the bore-size limitation, if such a limitation ever existed.

With reference to Mr. Woolson's remark about there being a limit to the available room for an engine and his inference that, therefore, a long stroke may be forced on an organization, why permit engine fundamentals to be a secondary consideration? Why should existing wheelbase be considered sacred? What advantage can be offered the driving public by holding to a given wheelbase to offset the disadvantage of a crowded engine?

DETONATION TENDENCIES

A MEMBER:—One point in favor of the small bore and long stroke has not been mentioned; that is, the effect of piston diameter on the maximum compression that can be used, and therefore on the efficiency of the engine as a whole. Every time we add ⅛ or ¼ in. to the diameter of a piston, we increase the detonating quality of the cylinder, because the additional ⅛ or ¼ in. results in slightly lower compression.

MR. TAUB:—We readily admit that the small-bore engine has advantages as regards detonation, if combustion-chambers in vogue four to five years ago are considered. However, we know today that we can manipulate combustion-chamber architecture and obtain a much greater gain in available compression-ratio without detonation than was possible by using a small bore in connection with the former type of combustion-chamber. In fact, the limiting factor is no longer detonation; it is thump or roughness, and this limitation is reached much sooner in a small bore than in a large bore. This objectionable phenomenon is caused primarily by the rate of pressure-rise obtaining throughout combustion. Because of the natural broad flat design of combustion-chamber prevailing where large bores are used, combustion is relatively slow; hence, the rate of pressure-rise is slow and, since the chamber is "roomy," it lends itself to development. But the small-bore-engine combustion-chamber is of necessity compact; that is, it must be very high for its width. Therefore, the rate of pressure-rise is high and it is apparent that there is very little that can be done to eliminate roughness except to lower the compression ratio.

Motor Transport in India

IT has been such sudden transition from the "fiton" (phaeton) and the "bund gharry" (the closed, box-shaped carriage) in Calcutta, and from the victoria (bittooria in Indian parlance) in Bombay, to the taxicab, that those who, five or six years ago, regarded the horse-drawn carriage and the bullock cart as permanent institutions have had a rude awakening. There were, before the war, about 5000 horse-drawn hackney carriages in Calcutta; today there are not more than 3000, and the first-class phaeton type of carriage, formerly largely patronized by Europeans, has practically disappeared from the streets. In Bombay, also, the hackney carriage has given place to the taxi.

Perhaps in no other city has the motor omnibus sprung so suddenly into popular favor as in Calcutta. Three years ago, the rare appearance of an old double-deck London bus on the streets was one of the wonders of transport, and there were a few covered-top buses maintaining feeder services for the tramways. Then came the announcement that the police were prepared to consider applications for licenses for running buses in the streets, and, within a week, buses of all shapes, makes, and sizes were swarming in Chowringhee, the Nevsky Prospect of the city. These buses were entirely Indian-owned, and many of them bore signs of having been assembled hurriedly. There were Overland, Ford, Chevrolet, and other engines of American manufacture in buses constructed locally, with seating accommodation in some cases for only 14 passengers.

THE FINANCING PROBLEM

The cult of the motor omnibus is extending to areas beyond the large towns. As may be imagined, the services established in Calcutta and in some of the neighboring towns were not as efficiently organized, from a financial point of view, as the circumstances demanded. Many of the buses maintained all-night services, and began to show signs of stress before they were three months on the road. Whether the operators of these bus services would be able to secure capital when the time came to replace thir hard-worked buses by new ones was doubtful. The hire-purchase terms offered by sellers of truck and car engines did not present a solution of the financial problem of the operators of bus services. For this reason the subsidiary company formed by the Calcutta Tramways Co., Ltd., expressly for establishing extensive bus services in connection with the tramways, seems to have a better chance of success, because it has the existing organization of the tramway services at its command. In Bombay, the bus services of the tramway company have been organized to eliminate competition, and promise satisfactory development.

So far, however, we are only on the fringe of developments in motor transport in India, and in the majority of instances where feeder services have been established in districts having no railway communication between towns, or where the towns are at some distances from the railway stations, the vehicles employed have been put together by the local carpenter and the motor engineer; in some cases, indeed, the buses depend upon engines which have already done their day's work in Calcutta or Bombay. These services do not cover a corner of the vast area where motor transport will eventually spell prosperity for the agriculturist and the merchant, and where the bullock cart now holds undisputed sway. Large organizations, carefully planned and adequately financed, are wanted in place of the present haphazard system of organizing motor services in order to take full advantage of the enormous possibilities open to motor-transport enterprises.

STRUGGLE FOR TRUCKING SUPREMACY

More surprising still is the new development in the struggle for supremacy in the transport of goods between the motor lorry and the bullock cart. A year or so before the war, when an organized effort was made for the first time in Calcutta to introduce motor transport for goods in the city, it was argued that bullock carts were carrying goods at such a low rate per maund, or 80 lb., that they were beyond the reach of competition, even admitting the fact that one lorry did the work of ten bullock-carts and that the lorry handled goods more expeditiously. In 1913, there were barely more than 20 or 30 lorries in the city. Today there are hundreds of them; and, what is more significant, for long-distance traffic between Calcutta and towns within a radius of about 80 miles motor transport is employed in preference to animal transport.

What has stood in the way of a more speedy development of motor traffic outside the limits of the big cities is the condition of the roads. These roads were not meant to cope with heavy motor-traffic, but the creation of an organization such as the Road Board is sure to lead to widespread propaganda in favor of strengthening the existing roads in the rural areas and building new ones. There is, in fact, every justification for anticipating a complete modernization of the age-old system of transport in India within the next few years.—*Modern Transport.*

High Compression and Antiknock Fuels

By L. C. LICHTY[1]

ANNUAL MEETING PAPER — *Illustrated with* CHARTS

THIS paper is an analysis of the economic value of the use of high compression, from the viewpoints of fuel cost, carbon-removal cost and engine performance.

Charts and tables, based on ranges of fuel cost, compression ratio and cost of carbon removal, and on assumed increases in economy from the higher compression, are used to evaluate the economies that can be effected under these assumptions. The same methods can be applied with actual data to determine the economic value of a doped or improved fuel that makes high compression without detonation possible.

Methods are given also that will show the car designer what gains in power can be made by an increase in the compression. Attention is called to the fact that improvement in fuel economy under these conditions may not be so great as expected unless it is accompanied by a change in gear ratio.

In conclusion, the author argues for high compression as a means of conserving our resources of gasoline, which eventually will be exhausted in spite of unforeseen overproduction in the past.

IT has long been well known that the work obtained from the internal-combustion engine is a function of the ratio of compression. Analysis of the four-stroke cycle, assuming air as the working fluid, with constant specific heat, gives the relationship

$$\text{Efficiency} = 1 - (1/r)^{0.4} \qquad (1)$$

where r is the ratio of compression.

The most accurate theoretical analysis of the internal-combustion-engine cycle was made recently by George A. Goodenough and John B. Baker[2]. In this analysis the actual working fluid was considered, variable specific heats were used, and the temperatures and pressures at the end of combustion were based upon the theory of chemical equilibrium.

While this analysis does not take into account the heat loss to the cylinder-walls and the deviation from constant-volume combustion, the results show very accurately the relative value of compression-ratios. Fig. 1 gives the results of this analysis for a mixture of gasoline and the required amount of air. It also includes curves showing the air-standard efficiencies and actual results from tests by Ricardo.

FUEL COSTS

The cost of power depends upon the fuel cost and the thermal efficiency. Thus

$$\text{Cost of power} = \text{cost per gallon}/(\text{B.t.u. per gal.} \times \text{efficiency}) \qquad (2)$$

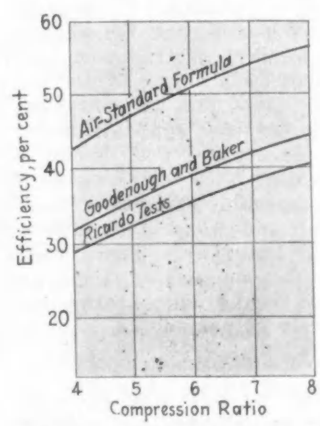
For a given gasoline price and assuming the heating value per gallon to be constant

$$\text{Cost of power} = K \times 10/e \qquad (3)$$

where K is a constant, and e is the thermal efficiency.

The values of $10/e$, which have been plotted in the upper full line of Fig. 2, show a decreasing cost of power with an increase in ratio of consumption. The relative costs from Ricardo's tests are plotted in a dotted line in the same figure, the relative costs being made to coincide at 5 to 1 with the result obtained from the theoretical analysis. The tests of Ricardo show virtually the same relationship between fuel cost and compression-ratio as did the theoretical analysis.

During the last few years, ratios of compression have been limited to 5 to 1 or thereabout, primarily because of the occurrence of detonation with higher ratios. With the advent of "doped" fuels and special cracked gasolines of high antiknock value, higher compression-ratios



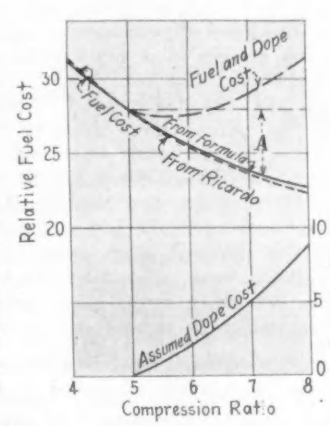


FIG. 1 (LEFT)—EFFECT OF COMPRESSION ON EFFICIENCY
FIG. 2 (RIGHT)—POSSIBLE EFFECT OF DOPE COST

The Maximum Desirable Compression-Ratio for the Assumed Cost of Dope Is Found at the Lowest Point of the Curve for Combined Cost of Fuel and Dope. *A* Is the Saving in Fuel Cost Due to Compression Above 5 to 1

are coming into favor. This immediately raises the question of what is the maximum desirable compression-ratio.

If a fuel is considered which will operate satisfactorily in an engine with a 5-to-1 compression-ratio without the use of dope, the quantity of dope required to give the same detonating characteristics for higher compressions, and consequently its cost, will be a function of $r - 5$. A third curve has been plotted in Fig. 2, based on the hypothesis

$$\text{Dope cost} = 0.075\,(r - 5)^{3/2} \times \text{relative fuel cost} \qquad (4)$$

Adding the ordinates of the two full-line curves gives a third curve representing the total cost of power. This

[1] M.S.A.E.—Assistant professor of mechanical engineering, Yale University, New Haven, Conn.

[2] See Bulletin No. 160, Engineering Experiment Station, University of Illinois.

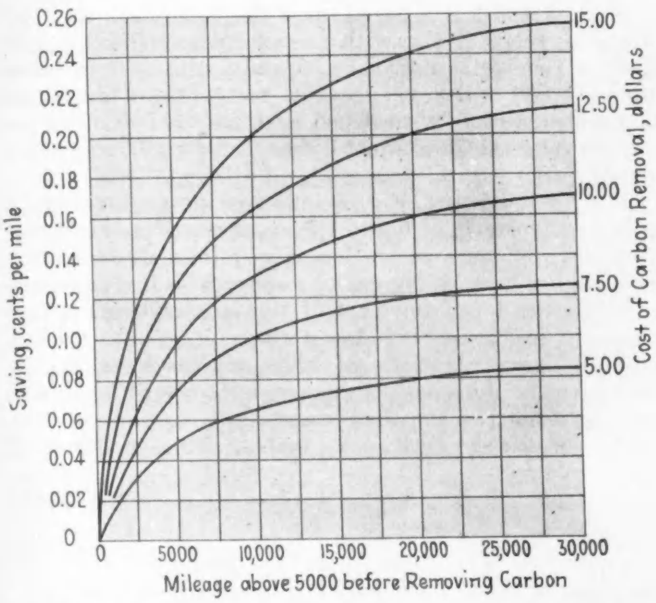


FIG. 3—SAVING DUE TO LESS FREQUENT CARBON-REMOVAL
Assuming the Cost of Removing Carbon at the End of 5000 Miles, the Various Curves Show the Saving in Cents per Mile for Additional Mileage Secured by the Use of Doped Fuel

curve has a minimum at a compression-ratio of about 5.75 to 1, which for this illustration is the maximum compression-ratio that should be used if cost of power is to be the minimum.

It might be possible to use a dope the cost of which, added to fuel cost, would not result in the minimum cost-value but would cause a decreasing total cost as the compression-ratio is increased. The result will depend not only upon the detonating characteristics of the gasoline and the design of the engine, but also upon the relative costs of the gasoline and the dope. With the foregoing condition, or any condition for that matter, it will be of interest to determine the price differential permissible to make the cost of fuel and dope at a given compression-ratio equal to the cost of fuel at the maximum compression-ratio practicable without the use of a dope.

TABLE 1—MAXIMUM PERMISSIBLE DOPE COSTS

Compression-Ratio	Relative Gasoline Cost, Cents per Gal.	Cost Decrease Units	Cost Decrease Per Cent
5.0	27.9	0	0
5.5	26.6	1.5	4.9
6.0	25.5	2.4	9.4
6.5	24.6	3.3	13.4
7.0	23.8	4.1	17.2
7.5	23.1	4.8	20.8
8.0	22.6	5.3	23.4

Table 1, prepared from data obtained from Fig. 2, gives the relative fuel-cost of power, the decrease in cost from that at a 5-to-1 compression-ratio, and the percentage that the decrease is of the total cost, all for various compression-ratios. The last column also represents the percentage by which the fuel cost can be increased by the addition of dope before the total cost will be greater than for a fuel not doped, with a 5-to-1 compression-ratio. If the fuel cost is increased, by the addition of a dope, by the amount indicated in the last column, no gain in economy will result from the use of higher compression.

Using these values, Table 2 has been developed for various fuel-prices and compression-ratios. As an illustration of its use, assume the price of gasoline to be 20 cents per gallon; in an engine with 6-to-1 compression-ratio, if the doped fuel cost is 21.9 cents per gallon no gain in fuel economy is obtained by using a 6-to-1 compression-ratio rather than a 5-to-1 ratio without the doped fuel.

From a fuel-cost viewpoint alone it is apparent that it is poor economy with low fuel-prices to have compression-ratios higher than 5 to 1 if doped fuel must be used. Referring to Table 2, it will be seen that, with fuel prices up to 30 cents per gal., a 6-to-1 compression-ratio would not justify a 3-cent differential between doped and standard fuel. With higher compression-ratios, however, there will be a decided advantage if the price differential remains the same, a 7.5-to-1 or an 8-to-1 compression-ratio showing a gain in fuel economy that more than offsets the 3-cent differential for any price of fuel given in the table.

TABLE 2—MAXIMUM PERMISSIBLE COSTS OF DOPED FUEL, PER GALLON

Gasoline Cost, Cents per Gal.	Compression-Ratio 5.5	6.0	6.5	7.0	7.5	8.0
15	15.7	16.4	17.0	17.6	18.1	18.5
16	16.8	17.5	18.1	18.8	19.2	19.7
17	17.8	18.6	19.3	19.9	20.5	21.0
18	18.9	19.7	20.4	21.1	21.7	22.2
19	19.9	20.8	21.5	22.2	23.0	22.4
20	21.0	21.9	22.7	23.4	24.2	24.7
21	22.0	23.0	23.8	24.6	25.4	25.9
22	23.1	24.1	25.0	25.8	26.6	27.2
23	24.1	25.2	26.1	27.0	27.8	28.4
24	25.2	26.3	27.2	28.1	29.0	29.6
25	26.2	27.4	28.4	29.3	30.2	30.9
26	27.3	28.4	29.5	30.5	31.4	32.1
27	28.3	29.5	30.6	31.6	32.6	33.3
28	29.4	30.6	31.8	32.8	33.8	34.6
29	30.4	31.7	32.9	34.0	35.0	35.8
30	31.5	32.8	34.0	35.2	36.2	37.0

Assuming a 3-per cent differential for the cost of dope, figures to the left of the heavy line indicate that, under the conditions there represented, the results of the high compression do not pay for the additional cost of doped fuel. Under conditions represented by figures on the right, the high compression pays.

CARBON-REMOVAL COST A FACTOR

Another factor to be considered, however, is that of carbon removal. A 5-to-1 compression-ratio engine can be operated a certain amount with standard gasoline before detonation makes carbon removal a necessity. At this point, if doped fuel were to be used, the engine could be operated a further amount before carbon re-

TABLE 3—COMPARATIVE FUEL-MILEAGE WITH VARIOUS COMPRESSION-RATIOS

Compression-Ratios 5.0	5.5	6.0	6.5	7.0	7.5	8.0
Miles per Gallon						
15	15.65	16.37	16.99	17.58	18.12	18.55
16	16.70	17.46	18.12	18.75	19.32	19.80
17	17.73	18.55	19.25	19.92	20.53	21.02
18	18.78	19.64	20.40	21.09	21.73	22.26
19	19.83	20.73	21.52	22.25	22.95	23.50
20	20.87	21.82	22.65	23.42	24.15	24.75

Assuming a mileage as shown in the first column for 5-to-1 compression, the successive compression-ratios may be expected to give the mileages listed under them.

TABLE 4—COST OF FUEL, IN CENTS PER MILE, BASED UPON 15 MILES PER GALLON AT 5-TO-1 COMPRESSION

Cost of Fuel, Cents per Gal.	Compression-Ratio 5.0	5.5	6.0	6.5	7.0	7.5	8.0
15	1.00	0.96	0.92	0.88	0.85	0.83	0.81
20	1.33	1.28	1.22	1.18	1.14	1.10	1.08
25	1.67	1.60	1.53	1.47	1.42	1.38	1.35
30	2.00	1.92	1.84	1.77	1.71	1.66	1.62

moval would be necessary. This will result in a saving which will tend to offset the doped-fuel cost.

If it be assumed that a 5-to-1 compression-ratio engine will require the removal of carbon at 5000-mile intervals, it is interesting to note what the saving will be if doped fuel is used all the time, resulting in greater mileage before removing carbon. With this assumption the curves in Fig. 3 have been drawn, various charges for carbon removal being plotted. It will be noted that the curves rise quickly with increased mileage and tend to approach a constant value. The saving is best represented in cents per mile.

For comparison with fuel costs it is necessary to reduce the fuel cost to the same basis as that for carbon removal. Table 3 gives the miles per gallon for various compression-ratios corresponding to mileages of 15 to 20, at a 5-to-1 compression-ratio. Table 4 is based upon 15 miles per gallon at a 5-to-1 compression-ratio and gives the cost of fuel in cents per mile for fuel costs of 15, 20, 25 and 30 cents per gallon.

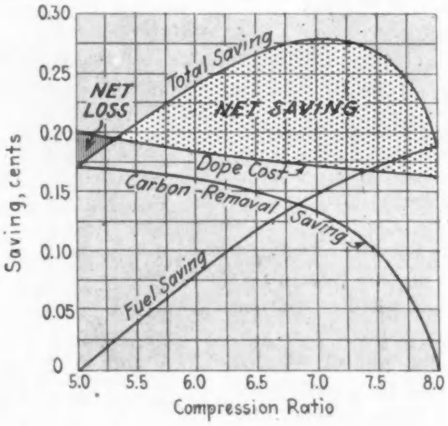
Plotting the fuel saving as found in Table 4, the carbon-removal saving as obtained from Fig. 3, and a third curve representing the summation of these two, gives the total saving. Plotting the dope cost on the same diagram, a comparison can be made between dope cost and total savings. This has been done in Fig. 4 for 15-cent gasoline and in Fig 5 for 30-cent gasoline. For both of these fuel-costs a considerable net saving is shown due to the use of doped fuel and high compression for all ratios except those below 5.25-to-1.

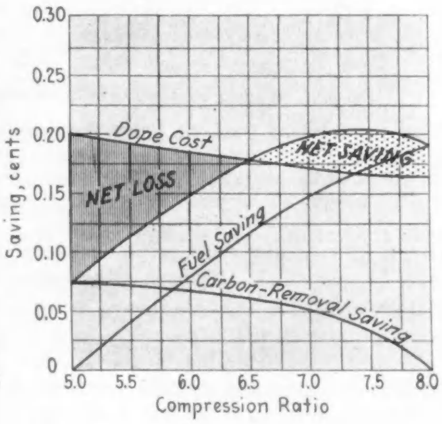
The shape of the carbon-removal-saving curve is based upon an assumption that, with an 8-to-1 compression-ratio and doped fuel, it would be necessary to remove carbon as often as with a 5-to-1 compression-ratio and standard fuel. In other words, only a given strength of doped fuel is considered, and the higher the compression-ratio is, the less is the mileage before carbon removal becomes necessary. Also, a straight-line relationship is used for compression-ratio and extra miles before carbon removal, the extra mileage for various compression-ratios being: for 5 to 1, 30,000 miles; for 6 to 1, 20,000 miles; for 7 to 1, 10,000 miles; and for 8 to 1, none.

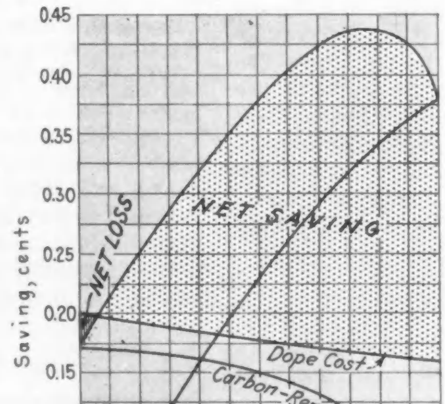
Figs. 6 and 7 are based upon the same data as Figs. 4 and 5, respectively, with the exception of the cost of carbon removal. For Figs. 6 and 7 the cost is based upon 10,000 miles per carbon removal for an 8-to-1 compression-ratio with doped fuel, and 40,000 miles per carbon removal for a 5-to-1 compression-ratio, also using doped fuel.

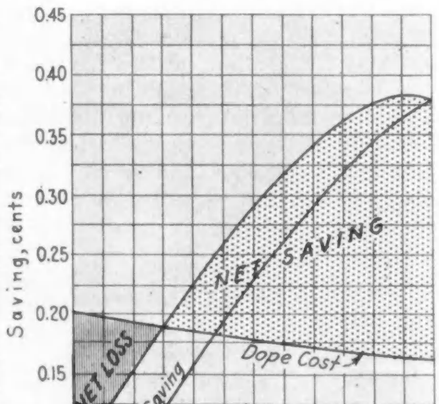
For low fuel-cost, Fig. 6 indicates no saving until a compression-ratio of 6.5 to 1 is reached. For the higher fuel cost, 30 cents per gallon, Fig. 7 indicates considerable saving when compressions above 5.75 to 1 are used.

While the foregoing part of this analysis refers particularly to the use of doped fuels, it applies also to specially prepared fuels of high antiknock value. In this case the dope cost is analogous to the difference in cost between the so-called standard fuels and the specially prepared antiknock fuels. This method of









NET SAVING RESULTING FROM HIGH COMPRESSION AND ANTIKNOCK FUELS

Fig. 4 Is Based on Gasoline at 15 Cents per Gallon Plus 3 Cents for Dope, a Gasoline Consumption of 15 Miles per Gallon, and an Expense of $10 for Removal of Carbon

Fig. 5 Is Based on Gasoline at 30 Cents per Gallon Plus 3 Cents for Dope, a Gasoline Consumption of 15 Miles per Gallon, and an Expense of $10 for Removal of Carbon

EFFECT OF HIGH COMPRESSION WITH LOW CARBON-EXPENSE

Figs. 6 and 7 Are Based on the Same Data as Figs. 4 and 5 Except for Carbon Removal Which Is on a Basis of 10,000 Miles with 5-to-1 Compression-Ratio and No Dope Fuel, and Other Mileages as Indicated in the Text

analysis, applied with actual costs and performance data, should indicate to the refiners the economic value of a specially prepared fuel which it is proposed to market.

Relation to Engine Performance

The third factor to be considered is that of performance. When high compression is substituted for lower compression, the power per cubic inch of displacement is increased. If no change in gear ratio is made, the horsepower-speed curve is raised and improved acceleration is obtained. In Fig. 8, *AB* represents the car resistance, *BC* the reserve power for acceleration at that speed, and *CD* the gain in reserve power for acceleration due to high compression. The relation between *CD* and *AC*, or the percentage of gain in power resulting from various compression-ratios higher than 5 to 1, based on Goodenough and Baker's curve, Fig. 1, is as follows: 5.50-to-1 ratio, 4.7 per cent; 6.0-to-1, 8.9; 6.5-to-1, 13.1; 7.0-to-1, 17.0; 7.5-to-1, 20.6; and 8.0-to-1 ratio, 23.9 per cent.

Thus, the manufacturer can produce a car having greater power and better performance with very little redesigning and almost no retooling of his plant by increasing the compression-ratio of the engine. Gains in economy, as indicated earlier in this paper, will be obtained also with full-load conditions, although these probably are of secondary importance to the manufacturer.

Actually, an automobile is operated only a very small part of the time under full-load conditions, and it is of interest to notice how the economy is affected under what may be termed level-road conditions. In Fig. 8 the curve marked Level Road Horsepower represents the power required on the level road at various speeds. This is the power the engine must develop to maintain constant speed, and consequently the engine will be operating under part-throttle conditions except at the maximum car-speed. It is obvious that the throttle opening will be less for the high-compression engine than for the low-compression engine when developing the power

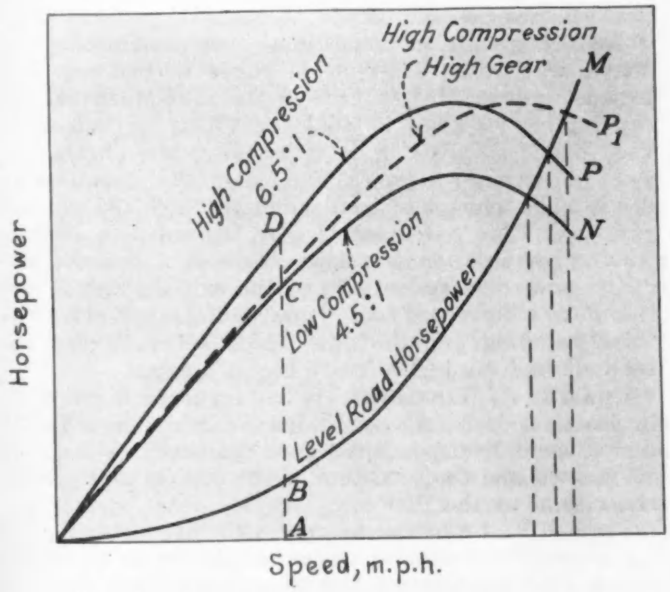


Fig. 8—Typical Engine-Performance Curves
The Gear Reduction Represented in the Broken Line High Compression High Gear Curve Is 17 Per Cent Less than That Represented in the Full Line High Compression 6.5:1 Curve

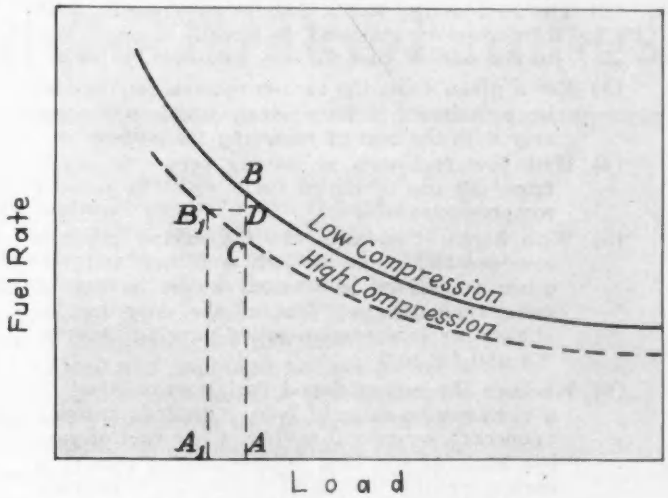


Fig. 9—Fuel Rates at Constant Speed

required for level-road conditions. The ratio of *AB* to *AC* is greater than that of *AB* to *AD*. The effect of smaller throttle-opening on the high-compression engine for level-road conditions is to reduce the economy.

Typical fuel-rate curves for both a low and a high-compression engine at a given speed are shown in Fig. 9. Since the high-compression engine must be operated at less load for a given speed, it can be seen that at these lower loads there is less gain from high compression than might be expected. Thus, fuel rate A_1B_1 would be obtained with the high-compression engine rather than the expected rate *AC*, and the actual gain in economy might be considerably less than would be expected from an analysis based upon full-load operation.

The expected fuel economy at level-road conditions can be obtained, however, by using a higher gear-ratio. This results in shifting the curve marked High Compression 6.5:1 in Fig. 8, to the right as shown in the curve marked High Compression High Gear, making it coincide partly with the curve marked Low Compression 4.5:1. The coincidence will be at the lower speeds and the result will be as follows:

(1) High-compression economy up to approximately one-half the maximum speed
(2) Approximately the same performance as with a low-compression engine up to half speed
(3) Greater acceleration from half speed to maximum speed
(4) An increase in maximum speed
(5) Slower engine-speed for a given car-speed

If it were possible to place some measure of value on the added performance resulting from high compression, which is obtained with little or no added expense in construction, this value could be added to the curves for total saving shown in Figs. 4 to 7, increasing the net saving and decreasing the net loss shown in these illustrations. This performance factor is valued very highly by both manufacturer and owner, and in many cases the owner will consider that the added performance alone justifies the cost of special fuel.

While many of the assumptions in this analysis may be somewhat far-fetched, a study such as this leads to the following conclusions:

(1) The carbon-removal saving resulting from the use of a fixed doped fuel is highest for the lowest compression-ratio, and vice versa

(2) The fuel saving has a definite relationship with compression-ratio and is directly proportional to the cost of fuel for any compression-ratio

(3) For a given dope, the carbon-removal saving will be principally a fixed item, which will vary only with the cost of removing the carbon

(4) With low fuel-costs no saving seems to result from the use of doped fuels with the present compression-ratios

(5) With higher fuel-costs the net saving becomes considerable. For 30-cent gasoline and the other conditions as chosen, a net saving of more than 150 per cent of the dope cost is shown for compression-ratios varying between 6.8 and 7.8 to 1

(6) Whether the use of doped fuel is economical at a compression-ratio of 5 to 1 depends entirely upon carbon-removal saving, a low cost of carbon removal and long mileage before removing carbon making the use of doped fuel uneconomical, and vice versa

(7) Under actual operating conditions at the lower speeds, the fuel economy resulting from higher compression with the existing gear-ratio will be less than expected from a full-load analysis

(8) The expected fuel economy, better performance at the higher speeds, a higher maximum car-speed and lower engine-speeds can be obtained by decreasing the gear reduction when decreasing the compression

Still another point should be mentioned. While this Country has been warned time and again of a possible shortage and of the exhaustion of the supply of petroleum, the story of one period of overproduction after another may give the impression that we have an inexhaustible supply of this natural resource. Eventually, however, we shall approach a period of shortage and probable exhaustion of petroleum fuel. The use of high-compression engines will delay the arrival of this time. Even though there may be a question as to any net saving to the consumer, high compression should be considered desirable as a means of conserving our natural resources.

THE DISCUSSION

CHAIRMAN O. C. BERRY[3]:—The fundamental law which forms the background of Professor Lichty's paper is well established in science and generally accepted among engineers. However, when we study the result of tests on a variable-compression engine in the light of our law, we often wonder whether the book is correct. It is obvious that the law cannot be applied to all running conditions of the engine with mathematical precision. Usually we find, after the whole thing has been threshed out, that something we had not taken into account has been upsetting our calculations and that after all the law applies more accurately than our first analysis indicated.

Some of my own personal experience has led me to wonder about our accuracy in applying our theories in connection with high compression and other factors that have come into the discussion of this paper. For instance, some tests that I have followed seemed to indicate that, when a car of given engine and rear-axle ratio is tested with normal compression and normal fuel and then with high compression and doped fuel, the increase in economy was more than we thought it was going to be, and more than theory calls for. I do no know how that happens nor whether the experience is general; but these tests involved a number of cars and many thousand miles of driving.

Another interesting fact is that, when we were studying on the dynamometer the increase in power from higher compression-ratio, the power showed a comparatively small increase at the lower speeds and a very large increase at the higher speeds.

D. P. BARNARD[4]:—One or two points in connection with Professor Lichty's paper have not been considered at all. One is in particular connection with the carbon-removal factor, as shown by Professor Lichty's curve, in figuring the value of anti-knock fuels. I realize that, by not having to remove carbon, the saving tends to infinity on the mileage basis as the compression drops. I think we could make one or two very justifiable assumptions in that connection. As we lower the compression, the time or mileage that we can obtain between top overhauls is actually determined more by the life of some part of the engine, as the exhaust valves, for instance, than by the amount of carbon which accumulates. It is not limited by what we call, for convenience, "silent power." In considering these things around our own laboratory, we usually talk about engine life or silent power, which is really more parallel to the customer's way of judging whether his engine needs overhauling. Most customers have carbon scraped out because the engine knocks unpleasantly, not because they are getting any interference with performance because of the carbon.

Another factor in connection with determining the shape of that carbon-removal curve is tied up with exhaust valves. In the case of the high-speed racing-car engine, we know it would be totally impossible to keep exhaust valves in it if we gave the engine the same breathing capacity and kept the compression down. The amount of heat going out with the exhaust gases would be too great to give the valves a chance. As the compression is raised, there is a definite tendency toward increased life of the exhaust valves and therefore a decreased cost of overhaul, carbon scraping, valve grinding and the like, which I believe has not been allowed for in Professor Lichty's paper.

CHARLES A. WINSLOW[5]:—It has occurred to me that, in practical operating conditions, probably the removal period would be dependent a good deal more on the kind of oil used and the condition of the pistons and piston-rings than on the fuel.

PROF. L. C. LICHTY:—I agree with Mr. Barnard that the reason for removing carbon is the knocking which occurs with the accumulation of carbon. Also, it is not a question of how the carbon is formed, but how soon it must be removed when using an antiknock fuel regardless of how the carbon is formed.

[3] M.S.A.E.—Director of engineering, carbureter division, Borg Warner Corp., Flint, Mich.

[4] M.S.A.E.—Research automotive engineer, Standard Oil Co. of Indiana, Whiting, Ind.

[5] M.S.A.E.—Consulting engineer, Sheet Steel Products Co., Michigan City, Ind.

Symposium on Modern Brake-Linings

Several phases of the subject of modern brake-linings were presented at a meeting of the Metropolitan Section, and these were discussed following the presentation of the three papers which are printed herewith. These several phases are dealt with in a paper on Development and Progress of Molded Brake-Lining, by R. H. Soulis; one on Modern Friction-Materials, by John Sneed; and a third on Brakes and Brake-Linings from a Service Viewpoint, by Oscar Eskuche. An abstract precedes each paper and the discussion.

The discussion relates to the general subject and includes an outline of a mathematical analysis of brake forces in a motor-vehicle as a foundation on which efficient design of brakes can be based; experiences of the operator of a brake-service station with regard to brake-testing and to brake-lining material of the molded and the woven types; a statement of ideal braking-requirements and the present status of brake difficulties; and a recommendation for a set of standards or designation numbers for each make and model of brake mechanism. Other major subjects considered are the effect of changes of the coefficient of friction of linings used with self-energizing brakes, and the conditions relating to the shift of the center of gravity forward when making a quick stop.

Development and Progress of Molded Brake-Lining

By R. H. SOULIS[1]

FIRST reviewing briefly the history of molded brake-lining, the author states that the introduction of molded lining has, until recently, met with considerable opposition. After the first volume-production adoption in 1924, there were no further adoptions of the strictly molded types in production until 1927, when the trend in brake design seemed to change suddenly from the external type to the internal type of brake. The present movement toward the use of molded brake-lining was brought about through the inability of woven lining to meet the exacting demands of some of the newer types of internal brake. In the author's opinion, the molded type of lining has more nearly fulfilled the present requirement of internal brakes than has any other type. He states that at least seven different brands of molded lining are now on the market, and that three of them are in large-volume production.

After discussing the characteristics of woven brake-linings, the author explains that the general procedure for the manufacture of molded lining is to mix the binding compound and the asbestos fibers thoroughly, press the mixture into plastic sheets and cut them into strips of the proper width and length, shape them, and cure them in molds which are subjected to pressure and heat. The complete intermixture of binding compound and fiber produces a homogeneous material that has a high degree of uniformity. The homogeneity of the material makes the kinetic friction nearly constant over a normal temperature-range. The material is practically incompressible and its consistency makes close machining possible.

Claims made by the author in favor of molded linings are that they are practically free from objectionable noises, are virtually incompressible, do not move on the rivets, and that it is possible to make them so that the coefficient of friction is uniform. There is only a small variation between the values of the kinetic and the static coefficients of friction, and molded linings add rigidity to the brakes.

In conclusion, the statement is made that, according to indications, a well-adjusted set of brakes equipped with molded lining will give a normal service of between 20,000 and 30,000 miles. The author is convinced that the surest way to improve upon the present brake is to add metal to the drums and use molded brake-linings. In his opinion, the brake-drum, and not the brake-lining, is the weakest part of the braking system.

THE molded brake-lining of 1918 was made by impregnating what is known as asbestos mill-board and curing the material while it was held in proper shape; it was then reinforced on the back by a thin piece of sheet metal. The company with which I was then connected endeavored to introduce this molded lining for use on passenger-cars and trucks. It manufactured this material for use on Ford transmission-bands. Several satisfactory tests on this material were obtained; but, because its adoption seemed so radical a departure from accepted practice, no great amount of enthusiasm was shown by car or axle manufacturers. Another lining manufacturer claims to have received an approval on his molded lining in 1918. The material was not adopted because the service stations and garages could not service such a material at that time. The two cases cited probably represent the first attempts to use molded brake-lining on pas-

[1] A.S.A.E.—Sales engineer, automotive equipment department, Johns-Manville Corp., Detroit.

senger-cars, although the feasibility of its use on cranes and industrial equipment had been known for some time.

From about 1918 to 1924, several types of molded lining were made in sample quantities. Several American manufacturers attempted to duplicate the English type of die-pressed liners. One found a way to treat asbestos fibers chemically, causing them to break down into a plastic mass which, in subsequent operations, was transformed into a hard and dense molded material. The first volume-production for equipment purposes occurred early in 1924, about the time that four-wheel internal brakes were making their appearance. It seems that more progress should have been made in the period from 1920 to 1924 if the materials actually had had merit; but in 1924 we did not know whether they had merit or not.

The Bureau of Standards became interested in the testing of brake-linings in 1921 and developed a testing machine which was generally adopted by brake-lining manufacturers for test and development work. This testing program, in which the Bureau of Standards became active, had a far-reaching effect upon the quality of brake-linings. When a manufacturer was developing a new lining it was specified that, to be acceptable, the lining must qualify with a certain wear factor. The testing machine served as a means for eliminating materials not qualified for further testing on road cars. Up to that time engineers had been concerned only with two-wheel-brake cars, and the testing-machine results had reacted unfavorably to molded brake-lining materials; their progress was halted for the time.

When four-wheel brakes were introduced it was noticeable that many features relating to brake-lining materials were encountered on four-wheel brakes that had been overlooked in connection with two-wheel brakes. It was not possible to obtain like results on different cars using the same type of four-wheel brake, and the lining manufacturer soon found himself making a different type of woven material for each make of car for which he was furnishing equipment. External brakes were the predominating type when four-wheel brakes were introduced. Brake-lining life was satisfactory, but the necessary pedal pressure was high.

Situation Changed by Internal Brakes

Difficulties with the linings in wet weather were overcome only by the incorporation of emery or a similar abrasive, which caused other difficulties. The practice therefore was not generally adopted and the situation remained almost unimproved until the adoption of internal brakes became more general and lessened the troubles caused by water, although they did not correct other difficulties presented by inherent properties of brakes and brake-linings. Molded lining, which had had a three-year trial on one group of cars, began to come into use at that time because of its ability to overcome some of the difficulties encountered with woven, folded, and compressed types of lining.

The introduction of molded lining has, until recently, met with considerable opposition; all the first adoptions were brought about only after each other possible combination of materials had been tried and found lacking. A factor that may have deferred the adoption of molded lining is the expenditure for equipment necessary to handle the material when curved to fit the shoes properly. Since the first volume-production in 1924, there were no further adoptions of the strictly molded types in production until 1927, when the trend in brake design seemed to change suddenly from the external type to the internal type of brake.

Molded lining was developed wholly on a basis of car performance. It is true that some of the first cars equipped with four-wheel brakes had internal brakes on the front wheels or on both front and rear wheels. At least two used woven linings having properties approximating those of molded linings. This probably was the start of the trend toward molded lining in production. It was followed the next year by the adoption in production of the first strictly molded material. Recent developments in molded materials include materials having holes and countersinks for the rivets molded in the material, as well as material reinforced with sheet-metal or coarse metal-gauze backing which offers a variety of quick-replacement possibilities.

Present Status of Molded Lining

The present movement toward the use of molded brake-lining resulted from the inability of woven lining to meet the exacting demands made by some of the newer types of internal brake. The shortcomings of the woven lining that chiefly brought about this condition were its tendency to produce noise, its lack of uniformity of friction coefficients, and an erratic condition that existed in the presence of moisture. At present, there are 25 volume-production cars using molded lining. As each new brake introduced since the adoption of four-wheel brakes has seemed to call for new brake-lining properties, so has the introduction of each internal type of brake seemed to call for properties entirely different from those required by external brakes. The molded type of lining has more nearly fulfilled present requirements of internal brakes than has any other type of lining; and we believe that, if the adoption of internal brakes becomes general, the adoption of molded lining will also become general.

At least seven different brands of molded lining are now on the market, and three of them are in large-volume production. The manufacturers of these three estimate their collective 1929 production conservatively at from 30,000,000 and 40,000,000 ft., an estimate based only on the production of cars that are at present using molded lining.

In our opinion the future brake-lining will be molded lining, since it is possible to incorporate in molded lining a higher degree of perfection because of its inherent properties and the manufacturing and assembling possibilities.

Characteristics of Woven Linings

It is possible that woven linings may be developed that have properties as favorable as those of the better-grade molded-linings of today. To accomplish this it would be almost necessary, in my opinion, to use a binding compound or impregnating material that is less susceptible to temperature changes than any of the vegetable oils, coal-tar products, asphalts or asphaltites, or other bituminous hydrocarbons now employed for impregnating brake-lining fabric. I believe that a suitable compound incorporated in yarn having a higher percentage of asbestos than is at present standard practice would make a woven lining which would be highly satisfactory if this yarn were woven into a very compact fab-

ric, subjected to hydraulic pressure, cured so as to remove all volatile constituents, and had the cure carried to a point at which the temperatures are higher than those that occur in normal service. The resultant product would practically be a molded lining, and the material doubtless would be rigid enough to require shaping to assemble it on brake-shoes.

The 800,000 cars now in active service, equipped with molded lining, cause less than 10 per cent of the number of complaints previously received on account of woven linings. We feel that this indicates the successful future of molded linings.

Except for minor differences in yarn size and weave construction, most woven linings are similar in composition up to the impregnating operation. This usually consists in passing the fabric through a bath of impregnating compound. It is exceedingly difficult to impregnate an asbestos fabric uniformly, because asbestos fiber acts like a filter and allows some of the solution to pass through it and a larger percentage of the compound usually is deposited on the surfaces of the fabric. The impregnating compounds—vegetable oils, coal-tar productions, asphalts, asphaltites, or other bituminous hydrocarbons—are very susceptible to temperature changes. With woven linings, it has seemed to me that a high-grade fabric was made and then that the element which caused trouble was introduced in the form of an impregnating compound.

The average yarn used in woven lining which meets the underwriters' specifications is 80 per cent asbestos and 20 per cent cotton, by weight. The cotton represents about one-third of the volume, and the complete loss of this cotton would reduce the thickness of the lining approximately one-third. I mention these facts merely to indicate the variables that are encountered and the extreme difficulty of making a homogeneous material in this way. Folded and compressed linings are subject to similar variations.

Manufacture of Molded Linings

The general procedure for the manufacture of molded linings is to mix the binding compound and the asbestos fibers thoroughly, press the mixture into plastic sheets, cut them into strips of the proper width and the required length, shape them, and cure them in molds which are subjected to pressure and heat. The complete intermixture of binding compound and fiber produces a homogeneous material that has a high degree of uniformity. These binding compounds can be chosen so that the resulting product is less susceptible to temperature changes within normal brake-operating conditions. The homogeneity of the material makes the kinetic friction nearly constant over a normal temperature-range, but there is a small variation between the kinetic and the static values of the coefficient of friction. The material is practically incompressible, and its consistency makes it possible to machine the brake-lining to close limits.

In most cases the lining is drilled and counterbored by multiple-spindle drills which travel radially, and the shoes are drilled at the same time the lining is being drilled and counterbored. Thus, while the drilling and counterboring operation requires more time than did the old method of punching woven material in flat strips, an operation is really saved. Owing to the greater tensile strength of most molded linings, the rivets can be countersunk to a greater depth, thereby permitting a greater amount of lining wear before the rivets contact with the brake-drums.

After the lining is riveted to the shoe, the shoe is mounted on a fixture and the surface of the lining is ground to a certain predetermined curvature. This operation removes all of the inaccuracies that may have occurred in the shoe assembly and also assures perfect initial seating of the brakes. In some cases a burnishing operation is performed instead of grinding and, with some types of molded lining, this is as effective as the grinding.

Advantages of Molded Linings

I shall make no claims for molded brake-lining, with respect to slippage caused by a film of water, that cannot be made for woven lining, except that moisture or small amounts of water seem to cause erratic conditions with woven linings that make the brakes too effective; but I have no record that this effect exists with molded lining. One brake company had considerable difficulty with woven lining because of this effect of moisture, but the trouble was eliminated when molded linings, which are virtually impervious to moisture, were adopted. We feel that the internal brake has greatly reduced the amount of trouble caused by brakes slipping when wet.

Molded linings have been practically free from objectionable noises, as they add rigidity to the brake, do not move on the rivets, and it is possible to make them so that the coefficient of friction is uniform.

No difficulties have been encountered with molded lining from any heat condition developed in normal service. Under severe high-temperature service, molded linings are subject to the same difficulties as woven linings because the main constituent in both types of material is asbestos, which begins to lose its water of crystallization at 725 deg. fahr., and this represents about 14 per cent of its total mass. As this water of crystallization is driven off from the asbestos fabric, the structure of the fibrous crystal is destroyed and the material is weakened structurally.

There has been a preponderance of opinion that molded linings cause far more drum-scoring than woven linings, but cases of drum-scoring are very rare except where steel has become imbedded in the lining. In such cases the results will be the same whether the lining be molded, folded and compressed, or woven. Our contention is that the lining does not cause the scoring, but that it is caused by the dust that collects on the drums. On analysis, dust will be found to contain steel, silica, and some carbon. Carbon and some silica are in the lining. When dust collects in spots between the lining and drum and is subjected to extremely high temperatures, its constituents melt and become imbedded in the lining. The steel so imbedded is harder than that of the drum. It scores the drum and in some cases destroys the lining. Pyrometer readings indicate a surface temperature of 1000 deg. fahr., but temperatures far exceeding this must exist in the spots where steel dust collects at the surfaces of the lining and the drum. That the steel is actually melted is clearly indicated by the fact that the steel imbedded in a woven lining shows the impression of the weave of the lining.

The indications are that a well-adjusted set of brakes with molded lining will give a normal service of between 20,000 and 30,000 miles. We have records of many cases, even on factory test-cars, in which 50,000 miles has been obtained and the lining was only about half

worn out. A large number of cars equipped with molded brake-lining are on the road, and the records indicate that the wear is generally more satisfactory than it was with most woven linings, although we pay tribute to the excellent wearing qualities of certain types of folded and compressed lining. We believe that, as the use of molded lining continues, we shall be able to improve upon its present properties and develop a material of a much higher degree of perfection than can be hoped for with present types of woven brake-linings which are now on the market.

Hardness of Brake-Drums

Our information on the merits of drums of various degrees of hardness is somewhat contradictory, although we are fairly sure that the use of high-carbon drums does not solve the scoring problem. Some of the severest scoring has occurred on high-carbon drums. We feel that the real solution is to add more metal to the drums, as this increases their rigidity and enables them to dissipate more heat.

It is my understanding that the chief reasons for the lightness of the existing brake-drums are that engineers hesitate to add to the unsprung weight of the car, and that reduced wheel-diameters have brought about reduced drum-diameters. It has recently been brought to our attention that one manufacturer has added 120 lb. to his brake-drums and brake shields or backing plates. I feel that the additions of weight should be carried to the extent that the weight is increased as much as possible without introducing any of the dangers resulting from using wheels of too great weight. The element of cost is no doubt a consideration, but I am convinced that if better brakes are desired the surest way to improve upon the present brake is to add metal to the drums and use molded lining. It is my opinion that the brake-drum, and not the brake-lining, is the weakest part of the brake.

Modern Friction-Materials

By John Sneed[2]

IF brake-lining manufacturers would insist on holding the values of friction coefficients to 0.3 or 0.4, many of their troubles would cease, in the opinion of the author, who asserts that the main objections to high friction-coefficients are rapid wear, greater liability to cause scoring, and instability.

The first results of tests on molded brake-lining materials were so superior to tests on woven material that further development of molded materials was carried on. Regardless of the type or make of molded material tested, it was found that the friction-coefficient value remained much more uniform than did that of woven material and that, without exception, the friction value and general characteristics of molded material were not changed by wear conditions.

Molded material shows longer life than woven material, according to tests, and the author thinks that possibly this is because of the completeness of the saturation of the molded material. Discussing the wide variation of friction-coefficient values, usually found in woven material and absent in molded material, the author feels that atmospheric moisture is responsible, and that woven material is affected to a much greater degree because of a much deeper penetration of moisture. In conclusion, he states that molded lining usually reaches its full efficiency after about 300 miles of service. It resists oil to a marked degree and, after it has been running in oil for some time, it can be succesfully restored by washing in clean gasoline.

ONE of the major problems in brake building is to provide for pedal-effort requirements that are low enough, without increasing pedal travel and sacrificing reserve travel. This difficulty usually leads to increasing the friction coefficients to a rather dangerous value. The brake-lining manufacturer may be called upon to furnish lining having a coefficient as high as 0.6 or 0.7, which forces him to "dope" the asbestos and produces about the same results that are found after "doping" a racehorse. The effects may be satisfactory for a short time, but they cannot last. If the manufacturers would insist on holding the values of friction coefficients to 0.3 or 0.4, many of their troubles would cease.

The main objections to high friction-coefficients are rapid wear, greater liability to cause scoring, and instability. The last mentioned is the most dangerous. On testing brake-linings having a normally high coefficient, we have found that the friction value of the lining sometimes would change as much as 100 per cent. These changes seemed to coincide with certain weather conditions. If the pedal effort required were normally light, very severe braking-action might result in damp weather, or very high pedal-effort might be required in hot, dry weather. We also had the problem of keeping the brakes quiet over this extreme friction-range. The greatest change was noticed with the woven linings; and the more the linings became worn the greater became the change. It was this erratic friction-value in woven materials that first convinced us of the merits of molded friction-material, since we felt that molded material had a structure that at least was uniform in composition.

The results of our first tests on molded brake-lining material were so much superior to those on woven material that we felt encouraged to continue the development of molded materials. Regardless of the type or make of molded material tested, we found that the friction-coefficient value remained much more uniform generally than did that of woven material and that, without exception, the friction value and general characteristics of molded material were not changed by wear conditions. In spite of the fact that a great variety of binders and saturants had been used in making up the dif-

[2] M.S.A.E.—Chief engineer, brake division, Midland Steel Products Co., Detroit.

ferent molded linings, we were led to the conclusion that the disposition of the asbestos fiber in the finished material was the determining factor in overcoming friction-coefficient changes caused by weather conditions. But we found that friction coefficients did not remain uniform over a wide range of temperatures, even on molded materials; 300 to 350 deg. fahr. seemed to be about the temperature at which most linings tested began to show a definite drop in friction value. Some showed such a marked drop that they were considered unsafe for braking on hills; however, the majority of the others held fairly high friction-coefficients up to about 600 deg. fahr.

Our tests on woven material have shown about the same general results in regard to temperatures, except on a few specimens which showed a marked increase in friction caused by "bleeding." This is a trouble we have never encountered on molded material, nor have we ever experienced "creeping" of the lining on the rivets.

Almost without exception, molded material shows longer life than woven material in our tests. Possibly this is because of the completeness of the saturation of the molded material. Before saturation, one type is very similar to thick blotting paper, and its complete saturation is as easily accomplished. Compare this task with that of saturating a piece of heavy, closely woven canvas. Another type of molded material is made into a homogeneous mass and has all the elements of the lining material in the mix. Some of the lighter saturants are driven off in the curing process, and a strong fibrous structure is left which is uniform throughout.

Variation of Friction-Coefficient Values

Although we are not lining manufacturers, we have evolved some theories as to the cause of the wide variation of friction-coefficient values usually found in woven material and not in molded material. We feel that atmospheric moisture is responsible, and that woven material is affected to a much greater degree because of a much deeper penetration of moisture. The asbestos fibers in woven material lie parallel to one another in the yarn and form a very effective wick to conduct moisture throughout the lining. Although the fibers may be stained or discolored in the saturating process, they are not sufficiently isolated from each other; hence, moisture coming into contact with a single fiber is transmitted to the entire group and causes a rapid temporary drop in friction value. As soon as a few brake applications have been made, the moisture is dried out and the lining returns to its normal condition.

Efficiency of Molded Lining

Contrary to general opinion, molded lining is not particularly difficult to handle in production. It compares very favorably with woven material in the matter of application to the brake-shoes. It is necessary to drill and countersink for the rivets, but I believe this is the accepted method for woven material also.

One serious fault of molded lining is its inefficiency when first installed. This seems to be partly because of the small amount of surface contact to be had without burning in; all molded materials tested seemed to require a certain amount of aging on the brake-shoe before reaching their full efficiency. This characteristic has caused molded material to be condemned in many cases, but I believe that a satisfactory surfacer can be developed which will give it full efficiency from the start and wear out and disappear as the brake-lining wears in.

Molded lining usually reaches its full efficiency after about 300 miles of service. We have not found it satisfactory for external brakes, mainly because sand or other foreign substances cause rapid wear or cutting. It resists oil to a marked extent and, after it has been running in oil for some time, it can be successfully restored by washing it in clean gasoline.

Brakes and Brake-Linings from a Service Viewpoint

By Oscar Eskuche[3]

A TABULAR statement in which comparisons are made between acceleration and deceleration is presented by the author as proof of the need of frequent and scientific maintenance practices with regard to brakes.

From the viewpoint of service, the author believes that the engineer's findings as to what constitutes the best lining for the particular brake he has designed for his particular car must be adhered to strictly. No one brake-lining will work equally well on all cars. In reconditioning used cars of any make, he has purchased the lining supplied by the manufacturer of the particular make of car when possible.

Although water affects brakes equipped with molded linings, the trouble is only momentary, according to the author, because the heat quickly dries off the surface moisture. Squeaks are seldom caused by the molded lining itself, but mostly by protruding rivets, out-of-round brake-bands or brake-shoes, foreign matter on the linings, or eccentric adjustments.

In conclusion, and because the author considers the brake linkage and brake adjustments to be the main causes of trouble, he emphasizes the importance of having every brake joint, lever and clevis-pin in good working order and thoroughly lubricated. He acknowledges that brake-testing machines have assisted considerably in adequate maintenance of braking systems, but says that it is well to remember that a brake-testing machine is only a measuring instrument.

MOST dealers in automobiles and owners of cars have given almost no thought to the facts set forth in Table 1, and they fail to realize the stupendous task that brakes must perform under present-day operating-conditions, when cars must be stopped from speeds of 20 to 50 m.p.h. The figures suggest the need of frequent and scientific brake attention. They are for a car weighing 3500 lb., operated by a $3\frac{1}{4} \times 4\frac{1}{2}$-in. six-cylinder engine. The car was equipped with four-wheel brakes and 30-in. tires, and had an axle

[3] General service manager, Warren Nash Company, New York City.

TABLE 1—COMPARISONS BETWEEN ACCELERATION AND DECELERATION

	Acceleration to		Deceleration from	
Speed, m.p.h.	20	50	20	50
Time, sec.	8.75	21.80	137	3.43
Distance, ft.	128	795	20	125
Power, hp.	9.75[a]	24.40[a]	62.5[b]	154.5[b]

[a] Theoretically expended at the rear wheel.
[b] Transformed into heat and mostly absorbed by the brakes.

ratio of 4¾ to 1. Under good operating-conditions an enormous task is demanded of the brakes as compared with what the engine has to do, and the difference in the amount of work done is purely a matter of the time and distance in which the work is done.

If the engine has 21.8 sec. in which to get the car rolling at a speed of 50 m.p.h. and the car is stopped in 3.43 sec., or say in one-sixth of the former period, about six times more power is consumed in stopping than in accelerating. If 795 ft. is allowed in which to get the car up to a speed of 50 m.p.h. and it is stopped in about one-sixth of that distance, six times more power must be applied than is used in getting the car rolling. It is regrettable that the motoring public has not been educated to an understanding of these facts. When operators do understand them, they will appreciate better

(1) What a tremendous task motor-vehicle brakes are called upon to perform
(2) Why brake-lining wears out
(3) That brake-lining is intended to be worn out, so that other parts of the car which are more costly to replace can be saved from wear
(4) Why brakes need frequent and scientific attention, if such great forces are to be controlled by moderate pedal-pressures
(5) Why safety on the highways depends upon intelligent and accurate brake-maintenance

Choice of Suitable Brake-Lining

From the viewpoint of service, I believe that we should adhere strictly to the engineer's findings on what is the best lining for the particular brake he has designed for his individual car. He has time, facilities and proving grounds for making exhaustive tests, and we in the service field do not have them. There is no one lining which will work equally well on all cars. Watching the performance of a certain kind of lining that has been installed on a car and trying to verify claims that "the lining is better than the factory lining" is so much time wasted. So many variables exist that cannot be determined in the field that if one does not want to take the engineer's word for the proper lining to use he might as well buy any lining. I believe I have bought as many kinds of lining as has anyone in the service end of the business; but, since 1924, I have taken the engineer's word as to the proper lining. In reconditioning used cars of any make, I have purchased the lining supplied by the manufacturer of the particular make whenever possible, and I believe my brake-lining worries have been less than those of most others. I can present no authentic data as to comparisons between woven and molded linings, as braking requirements have changed entirely since 1924; but I have less trouble reconditioning used cars that are equipped with molded linings than I do with those that have woven linings.

Miscellaneous Considerations

Although water affects brakes equipped with molded linings, the trouble is only momentary because the heat quickly dries off the surface moisture. Squeaks are seldom caused by the molded lining itself, but mostly by protruding rivets, out-of-round brake-bands or brake-shoes, foreign matter on the linings, or eccentric adjustments. These are also causes of scored drums, rather than that the lining scores them. The more rapid wearing of brake-drums today can be ascribed to the greatly increased car-speeds, in my opinion, rather than to the brake-lining used. Molded linings can be manufactured that are of more uniform composition and are easier to apply than woven linings.

I attribute one real trouble directly to the molded lining; that is, the impossibility of ever getting oil completely out of an oil-soaked piece of such lining.

The brake linkage and adjustments are mainly the causes of trouble; so, the importance of having every brake joint, lever and clevis-pin in good working order and thoroughly lubricated cannot be too greatly emphasized by the service man. The customer is usually ignorant of how important brake adjustment is. Instead of telling an owner that it is necessary that the brakes and other parts be well oiled and adjusted and charging him a reasonable price, the average brake-adjusting station does the customer an injustice by trying to adjust the brakes without first seeing that all the brake mechanism is free and well oiled.

The figures in Table 1 and the foregoing statements should prove the need of frequent and scientific brake attention. The owner and the mechanic should see that taking the engineer's advice on lining, keeping the brake linkage in good working order and well lubricated, keeping the drums round, keeping the proper lining-clearance, and obtaining some knowledge of the extremely heavy service required of brakes with the present-day speed will greatly minimize brake troubles.

Brake-testing machines have done a great deal to help; however, it is well to remember that a brake-testing machine is a measuring instrument and nothing more. It does not make adjusting, oiling or relining any easier, but eliminates road testing and guess-work.

THE DISCUSSION

An outline is presented with regard to a mathematical analysis of braking forces in a motor-vehicle as a foundation on which efficient design of brakes can be based. By the means outlined, the dynamic braking-load can be computed.

Experiences of the operator of a brake-service station with regard to brake-testing and to brake-lining material of the molded and the woven types are related, and this operator is convinced that molded lining is not desirable on any brake operated by foot power unless the braking mechanism was specially designed for using molded brake-lining material. Ideal braking-requirements and the present status of brake difficulties are stated by another discusser who believes that a set of standards or designation numbers for brake mechanisms should be devised.

A discussion of the effect of changes of the coefficient of friction of linings used with self-energizing brakes is included, as well as of conditions relating to the shift of the center of gravity forward when making a quick stop.

PROF. E. H. LOCKWOOD[4]:—I have been interested in the problem of a mathematical analysis of braking forces in a motor-vehicle, as a foundation on which efficient design of brakes can be based. Mention may be made of one striking fact brought out in this analysis. The weight on the front and rear wheels is a fixed quantity only when the vehicle is at rest, or when moving at constant speed. When the car is being slowed-up by the brakes, the static wheel-weights are altered by adding a dynamic load to the front wheels and subtracting an equal load from the rear-wheel weight.

The dynamic load can be computed. For a given car, it varies directly with the amount of deceleration produced by the brakes. For four-wheel brakes fully applied, the dynamic force may be as much as one-third of the rear-wheel weight. Accordingly, if the rear-wheel weight were 2100 lb. with the car at rest, this might be reduced to 1400 lb. at the instant the brakes were fully applied, with likelihood that the rear wheels would lock. The dynamic load taken from the rear wheels is added to the front-wheel load; hence, in the foregoing numerical example, 700 lb. will be added in front. To secure maximum braking-efficiency, it will then be necessary to reduce pressure in the rear and to add to the front braking-pressure.

The best distribution of brake-shoe pressure, front and rear, is a matter to be settled by experiment rather than by theory; yet the computations have value as showing the limits of braking forces dealt with. When the brake-shoe pressures, front and rear, have been fixed, the stopping forces acting at front and rear can be computed, giving an over-all brake-efficiency for the given assumptions.

SERVICE-STATION EXPERIENCE OUTLINED

C. P. GRIMES[5]:—In addition to operating an independent brake-service station at Syracuse, N. Y., I have seriously attempted to keep posted on brake-service development by visiting many places of interest each year —such as brake, brake-lining, automobile and motor-truck plants, and brake-service stations—to learn what I could of brake materials, brake designs and service-station equipment. In July, 1928, I installed a new specially built drive-through brake-service station; it is 84 ft. long and has mounted in it flush with the floor a four-wheel-brake tester and a wheel aligner of my own design. The tester will record in pounds the retarding force acting at the tread of each tire at the moment of stopping. The aligner will detect the change in alignment brought about by a change in tire pressure from 30 to 40 lb. per sq. in. in a balloon tire of 19 x 5.50-in. size. The brake load on each of the four wheels, as well as the trend and amount of misalignment on the front and the rear wheels, can be recorded in less than 2 min. per car without the driver leaving his seat. This equipment has been of great assistance to the local tire-dealers.

The brake-service station of the future must be equipped to deal with so many different mechanisms and operating conditions that, to give the public satisfactory service, a trained engineer with a full knowledge of all kinds of brakes will be required. I stock eight kinds of brake-lining, so as to have for each job that material which will please the owner best.

Molded brake-lining material has less gripping power than woven lining, is much harder to work, very rigid, and produces many scored drums; oil makes it slip and grab as badly as does any other kind of lining. However, molded brake-lining material often can be cleaned more effectively than can many woven linings. Car manufacturers may prefer molded lining because it is less likely to cause squeaking, and, on account of the lower gripping-power, there is less chance for a variation in the stopping ability of the four wheels. Car manufacturers attach lining to newly ground cylindrical surfaces that soon come into full contact with molded brake-linings, but the brake-drums that I service are seldom smooth and cylindrical. My customers demand quiet brakes with plenty of gripping power, that are not much affected by wet or dry conditions, and from which oil and grease can be removed.

I use a woven lining that is semi-molded, sufficiently flexible to be delivered in rolls and soft enough to adapt itself quickly to small variations in drum surface. This lining assures an excellent stop, is always quiet and is almost oilproof and waterproof. The life of the lining is good, and I have not been troubled with glaze. Fully 80 per cent of my relining work is caused by oil and grease; so, why worry about future increased mileage for brake-linings when the present mileage is almost never used completely? The car manufacturer may change his brake-linkage to compensate for the low gripping-power of molded material, but it is often very difficult for the service station to make the change.

One very good brake-system is designed expressly for molded lining of low coefficient of friction; it would grab severely if woven lining were used or if its surface became fogged with oil vapors. Molded lining is passing through an experimental stage; some is good and some is very poor. Apparently neither the branch house, the jobber nor any dealer has much faith in molded brake-lining; none of them in my locality will stock it. I have yet to be convinced that a molded lining is desirable on any brake that is to be operated by foot-power, unless that brake mechanism was specially designed for using molded brake-lining material.

IDEAL-BRAKING REQUIREMENTS

M. A. SINGER[6]:—Next to making an automotive vehicle self-propelling, it is necessary to keep it under control and to be able to bring it to a smooth stop as occasion may require. This demands the construction and proper functioning of a brake mechanism which will give performance to meet both the standards set by the car manufacturer and the everyday need of the car user. The retardation or stop of the vehicle should not be uncomfortable or endanger the lives of the passengers nor cause severe stresses in the car mechanism. All vehicle brakes should be designed so that there will be a rolling, velvet-like resistance that requires but low foot-pressure to obtain it. The things that must be

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[5] M.S.A.E.—Owner and manager, Grimes Brake Engineering Service, Syracuse, N. Y.

[6] M.S.A.E.—Research engineer, mechanical development, Bakelite Corp., Bloomfield, N. J.

considered in the design of a properly functioning brake are those influenced by some of the following items.

Brake-linings should be made of a material that will give long, uniform service under all conditions throughout the life of the lining, and have a definite and known coefficient of friction while in contact with a definite type of brake-drum under all conditions of weather and temperature. Brake-drums should be of a specific material having a known carbon-content and hardness. The type of brake mechanism, whether hydraulic, mechanical or servo-operated, should be such that it gives a definite unit-pressure and has a smooth cushioned effect, without producing grabbing or noise. I made no mention of noise in connection with brake-linings because, if noise and its causes are investigated, we find that high-frequency vibration exists. We cannot state that the lining itself is causing the noise; it may be caused by vibration in the brake-drum or brake mechanism.

The brake mechanism should be such that all brakes are properly synchronized under all weather conditions, and when the car is turning; for it is generally when the car is turning that skidding occurs. The ratio of the foot or hand-brake pressure to the pressure applied through the linkages to the brake-drums must be given due consideration. The mass or weight of the vehicle must be considered in relation to the total number of square inches of brake-lining in contact with the brake-drums.

Water and moisture are causes of poor performance of brakes. The time of recovery from a low coefficient of friction caused by water, which is a lubricant, to the normal coefficient of friction should be of the shortest duration. Combinations of brake-linings and brake-drums exist which cause what is known as "morning sickness" when first used after standing overnight. At the first two or three applications of the brake, the car stops with a jolt; then, at the next few applications, the brakes will not work. Some brake-mechanisms are so constructed that grit and mud easily lodge between the brake-lining and brake-drum.

These considerations and numerous others confront the car designer, the manufacturer, the car user, and the brake-lining manufacturer; for, no matter what the cause may be, the lining manufacturer must be the first one called upon to overcome all defects.

Present Status of Brake Difficulties

The present situation requires that the brake manufacturer make the material to suit conditions set forth by the car manufacturer; but, in reality, the brake mechanism should be designed in all its detail so that no part should call for a performance of another item which is beyond its capability. A design may call for a lining having a relatively high coefficient of friction and long-lfe, but this may cause defects such as noisy brakes and poor performance. The car manufacturer designs a braking system and expects the brake-drum manufacturer and the brake-lining manufacturer—two separate individuals—to use suitable materials and separately to make these parts so that they will work together satisfactorily in a mechanism that already has been designed and that is assembled by the car manufacturer. The importance to the car manufacturer seems to lie in the price, the degree of safety provided, and the length of life of the lining. The lining must last for three months at least; after that, the free-service period of the car will be ended. The manufacturer must make this brake-lining so that it will pass a test laid down by the car manufacturer; and no two tests as specified by any two manufacturers are alike.

Further, the brake-lining manufacturer in some cases must make a second type of lining, which goes to car owners and fleet operators, and this must give good uniform performance and have long life regardless of the make of car or truck on which it is used and the type of brake mechanism it has, no two layouts of which are alike on succeeding models. The owner seldom knows the make or name of the original brake-lining on his car or truck, but makes specific inquiry for replacement with regard to a definite make of lining he may have seen, heard or read about, or has been talked into considering by the representative of the brake-service station. That is where the lining manufacturer's product receives a close observation by the car owner. The lining selected by the owner may be wholly unsuited for his car or type of brake mechanism, and he roundly condemns the lining.

Standards for Brake Mechanisms

I believe we should inaugurate a set of standards or designation numbers for each make and model of brake mechanism, bearing in mind the various factors that influence performance, the numbers to correspond with the types of brake-lining and brake-drums that should be used with the specified mechanisms. For example, considering a piston-ring, we have a standard for thickness, diameter and the like, and these specifications are made by the car manufacturer. Why should not the car maker specify under which standard or designation number his particular brake mechanism comes, for each particular model of car? These standards should be determined by a committee appointed by the Society of Automotive Engineers or the American Automobile Association, and formulated with the cooperation of the passenger-car, motor-truck, motorcoach and brake-lining manufacturers.

Without any intent to criticize the S.A.E. Brake-Lining Subdivision that worked on this subject some years ago, the actual test-work done by the Bureau of Standards under meager appropriations from the Government has resulted in no definite suggestions or recommendations for conducting tests of standards of performance for brake-linings. The committee I suggest should be more in the nature of a rating committee such as exists in the American Automobile Association for tests of cars, and to which all car manufacturers would submit their new cars, together with detailed designs of the brake mechanism on the various models, for rating brake mechanisms in accordance with a set of standards or designation numbers. The expense of such work should, in my opinion, be borne by the car manufacturers, as it would be a service to their customers in replacing brake-linings, brake-drums and the like, and would also benefit the manufacturers.

George A. Sheller[7]:—What percentage of cotton is contained in molded lining?

Mr. Soulis:—Asbestos is the only fibrous material in molded lining.

Mr. Sheller:—Did Mr. Sneed find it possible to reduce the clearance, or was it necessary to make a greater clearance between brake-lining and brake-drum?

Mr. Sneed:—We use a 1/16-in. clearance, not to ac-

[7] A S.A.E.—Partner and sales manager, Ricardo Sales Co., New York City.

commodate the molded lining but so as to be able to leave the drum-surfaces unturned and use the drums exactly as they come from the punch-presses. We do not advocate turning or grinding drum-surfaces. We have found that 90 per cent of the scoring troubles are ended if the drums are unturned. We can utilize drums that run out of true as much as 1/32 in.

Friction-Coefficient and Center of Gravity Changes

S. G. Tilden[8]:—We serviced brakes on from 150 to 160 cars per day last year. I feel that this idealistic discussion of what should be designed and what results should be had is very fine from the viewpoints of design and manufacture, but those who must service what comes on the car are faced with a different problem. As we are not in a position to change the brake mechanism and design, we must accept the conditions as we find them.

Let me remark as to the effect of changes of the coefficient of friction of linings used with self-energizing brakes. In a simple non-energizing brake, we would expect the brake effectiveness to increase in proportion to an increase in the coefficient of friction of the lining, and a normal decrease in brake effectiveness with a decrease in the coefficient of friction; but, when we have a servo-mechanism the effectiveness of which also varies directly as the coefficient of friction, we have a variable depending upon a variable. Although, possibly, the final braking-effect does not vary as the square of the coefficient of friction, it varies as some power of it, and this is far different from a direct relation.

The coefficient of friction of any brake-lining changes continuously. Although these changes are not so great with molded linings as with woven linings, the change is often as much as 75 to 100 per cent. Thus, if the coefficient of friction is doubled, the effect of the servo-mechanism is also doubled, and, practically, we get four times the braking effect that we did originally. Conversely, if the coefficient of friction is halved, we get one-fourth of the original braking effect. So it is very difficult for us to maintain equal braking on the four wheels unless the coefficient of friction can be maintained a constant. This reverts to the problem of grease on the brake-linings, which changes the coefficient of friction so readily and so quickly. We find that the slightest trace of grease practically ruins brake equalization, and especially so when the braking effect depends upon a self-wrapping servo brake.

Regarding the shift of the center of gravity forward when making a quick stop, which Professor Lockwood brought out, it is evident that the front wheels can do much more than 50 per cent of the braking. Our former theory of 60 per cent of the braking in the rear and 40 per cent in the front now becomes obsolete if we design the brakes to get the best stop. Probably the percentage division to afford the best stop would be about 70 per cent on the front and 30 per cent on the rear. This is not generally advocated at present because of the possibility of locking the front wheels, with the consequent loss of steering-control on slick road-surfaces. Those who have driven cars equipped with hydraulic brakes, in which the division of braking effort is 25 per cent to each wheel, know from experience that the rear wheels will lock, on a quick stop, long before the front wheels are exerting their maximum possible braking-effect.

We have found that molded linings give very good results on brake systems designed for their use. However, they will not stand the abuse of high operating-temperatures. In that respect, woven lining has given greater protection than molded lining. With a good woven lining, properly made and saturated, temperatures under 450 deg. fahr. will not affect the future operation and life of the lining seriously; but such temperatures on molded linings cause them to disintegrate and "peel."

Consistent Performance of Molded Lining

Harold Nutt[9]:—We have used molded material in clutches, but have not used molded brake-linings; however, we have experimented with them during the last year, and our experience indicates that the molded lining is the coming thing. I say that because it has given consistent performance that we never were able to get with the woven linings, as we used a servo-type shoe in which a variation in the coefficient of friction is far more serious than it is with the plain-type shoe, non-servo construction.

Grease has two distinct effects on brakes; one of them is very dangerous, particularly on the servo-type brakes. A little grease on the lining mixes with the dust that collects in the drum and produces a tacky condition that greatly increases the coefficient of friction. The wheels then become virtually self-locking with the least bit of assistance from the pedal. Dragging the brakes a few moments will warm them sufficiently to get rid of this stickiness, and they will then operate satisfactorily. This trouble is not usually the fault of the lining; it is a fault of design; but it is difficult to control. A little oil can enter easily, and it creates a dangerous condition. A large amount of grease or oil on brake-linings makes a "hard" pedal, but this is a much less dangerous condition than the one just described. Will Mr. Sneed explain why the tacky condition apparently does not exist with molded lining? We have never experienced this condition which Mr. Grimes says does exist with the molded lining, and never have had anything but consistent performance. Even if a little oil or water enters, one still has a good brake.

Mr. Sneed:—The only explanation I can offer is that the lining is not subject to saturation by either oil or water. The grease is squeezed out at the edge of the linings during the normal application and before it reaches the tacky condition. We have seen many instances of cars that were running with grease on the drums. Just the condition that Mr. Nutt mentioned had occurred, but not at a critical place; the grease had collected along the edges of the shoes and the dust had collected along with the grease, but the surface of the linings was nearly dry and practically untouched by oil.

Die-Pressed Linings

Question:—Speaking of fundamental types of lining, the woven type which is afterward compressed is very different from the plastic type. Why was the compressed type eliminated?

Mr. Soulis:—The processes necessary to weave a material that can be compressed into as dense a mass as the present molded lining are too expensive.

[8] M.S.A.E.—President and treasurer, S. G. Tilden, Inc., Long Island City, N. Y.

[9] M.S.A.E.—Engineer, Durant Motors, Inc., Elizabeth, N. J.

QUESTION:—Is it not a fact that, in Europe, on very high-grade cars, they use a woven material?

MR. SOULIS:—It is not general European practice today to use die-pressed materials. I understand that they have been through the cycle of starting with woven linings, then having gone to the die-pressed type and gone back to the woven types because the service stations in Europe were not equipped to handle the die-pressed type. That was also the condition in this Country at the time molded linings were first introduced; but, with the higher type of service station that we have today, and modern equipment, they are in excellent position to handle the rigid type of molded materials.

QUESTION:—Assuming that one can get good service, how would a very badly scored drum be serviced?

MR. SOULIS:—The drum would be trued, and what was done with the lining would depend upon whether any steel was imbedded in it and on how badly it was worn.

SERVICE-STATION EQUIPMENT

QUESTION:—Is it true that 90 per cent of the service stations or garages that are using brake-linings today are not equipped to service them?

MR. SOULIS:—That statement probably is true; but it is also true that, even in communities as small as 25,000 population, there is at least one station to which other garages or service stations can take scored drums to have them serviced. While I am not especially informed on the resale field, I understand that conditions are being improved. A number of the brake-lining companies have what they now call Class-A service stations. To be so rated, a service station must have a four-wheel-brake tester, a complete set of wheel pullers, relining equipment, drum truers, and an assortment of felt washers to relieve troubles caused by grease.

A MEMBER:—Then in your estimation the use of molded brake-linings to solve brake problems is predicated on perfect brake-servicing conditions, as nearly as is possible?

MR. SOULIS:—That is a fair statement.

CHAIRMAN JOHN CREAMER[10]:—You recommend resurfacing a scored drum; when do you recommend that a drum be replaced? I ask because, in many instances in which brake-drums have been machined or ground, we have found that the brake-shoe travel would not compensate for the new diameter and that there was no braking effect. So, I think the brake stations should be trained in the matter of grinding and machining brake-drums on internal brakes. A grinder or a drum lathe in the hands of an inexperienced man is a dangerous instrument. It becomes the duty of the brake and car manufacturers to educate the service stations to that extent.

MR. SOULIS:—Possibly the amount of travel in the brake mechanism should be the limiting factor. I agree that this program of brake servicing should carry an educational program with it.

MR. SHELLER:—Is it not possible to install a thicker lining than the one recommended, after brake-drums have been made smaller by the factory?

MR. SOULIS:—I believe that would answer the purpose up to the point where the new lining had worn down to the difference in thickness which was permissible in the travel gained by using the additional thickness of lining.

MR. SNEED:—According to tests made in our laboratories, it is not necessary to resurface the drums after they are scored. All that is necessary is to install a piece of new brake-lining. We have found that as good results are had as from a brake-drum which is perfectly smooth. We recommend that the drums be not resurfaced.

CHAIRMAN CREAMER:—Does that not increase the rate of wear on the new lining?

MR. SNEED:—No.

TEMPERATURE EFFECTS

ALBERT WHITELAW[11]:—A remark was made that the molded linings outwear the woven linings. That may be a fact up to temperatures of say 350 deg. fahr.; but a molded lining is wholly dependent upon its organic material to hold it together and, on motor-trucks and motorcoaches, the temperature may be as high as 1000 deg. fahr., and no organic material known will withstand such a temperature. Hence, the molded lining will decompose; but, in a woven type of lining, the organic material is in the compound which is imbedded in the cloth, and the cloth holds this compound together even after the organic material is burned out. So, I believe that the molded lining will not stand up as well under extreme conditions as will the woven lining.

A MEMBER:—There should be a specification as to how high a temperature a brake-lining shall withstand. A brake-drum having flanges, as used abroad, will dissipate heat as rapidly as it is generated and keep the brake-lining temperature below a value at which the lining will disintegrate.

C. O'ROURKE[12]:—With four-wheel brakes the operating temperatures are much lower than with two-wheel brakes, because there is only a certain amount of energy to be dissipated in the form of heat and four brake-drums are available in place of two.

MR. SOULIS:—With four-wheel brakes a stop is being made in a shorter time; consequently, work is beind done at a faster rate. I am not sure what the variation in the amount of heat dissipated would be, as to how it compares when considering both two-wheel and four-wheel braking-systems. The shorter the distance is in which to make a stop, the greater is the power required; consequently, all that power is transformed into heat energy that must be absorbed in the drum and the lining.

To clarify an apparent misunderstanding about the value of the coefficient of friction that can be incorporated in a molded lining, I may say that there is no limit to the value that can be built up because a variety of compounds can be incorporated. It also is possible to make a molded lining that contains no organic matter. The volatile constituents, which are likely to be organic matter, determine the deterioration of any lining. I also believe that there is some misunderstanding in connection with the temperatures that are reached in brake service. We are sure that asbestos starts to disintegrate at 725 deg. fahr., regardless of the form of the friction material. Hence, if we cannot use heavier brake-drums to dissipate the heat and keep those temperatures down, possibly asbestos is not the material to use for brake-linings and we

[10] A.S.A.E.—Treasurer and general manager, Wheels, Inc., New York City.

[11] Manhattan Rubber Mfg. Co., Passaic, N. J.

[12] Development engineer, Staybestos Mfg. Co., Philadelphia.

may have to resort to the use of some other heat-resisting material.

MR. SNEED:—The reason the more serious heats were not encountered with two-wheel brakes was because the inertia of the car caused decreased loading of the rear wheels when braking, as indicated in Professor Lockwood's remarks. In brake testing on mountains, using thermocouples imbedded in the surface of all four of the brake-linings so that they came into rubbing contact with the brakes, we found that the maximum brake-temperature on Lookout Mountain in Tennessee was only 350 deg. fahr. The radiation at that temperature was as rapid as the generation of heat. So I think the practical limits are well within 600 deg. fahr. Higher temperatures probably are reached momentarily after very high-speed stops.

The Corn Belt

CORN is the leading field crop of this Country. The outturn averaged around 2,750,000,000 bu. during the five years from 1923 to 1927, and the Corn Belt, although it contains less than 8 per cent of the land area of the United States, produces two-thirds of the domestic crop and about two-fifths of the entire corn crop of the world.

The agriculture of the Corn Belt is more highly diversified and better integrated than that of any other section devoted to what is usually termed general farming. In addition to about two-thirds of the corn, it produces over 50 per cent of the oats, and 25 per cent of the wheat and hay. A most intricate livestock industry has been built upon the foundation of this grain and hay production, only the wheat and comparatively small proportions of the corn, oats and hay being marketed without conversion. The Corn Belt has about two-thirds of the swine and around one-fourth of the beef cattle of the Country. According to the United States Census of 1920, nearly two-thirds of the pure-bred beef cattle and 25 per cent of the registered dairy cattle are in the States of the Corn Belt, although a considerable proportion of them are in the parts of those States outside of the Corn Belt proper. In that region, also, originates nearly two-fifths of the National production of poultry and eggs. The livestock population of this region is probably heavier per acre than that of any other general farming area of any country.

AREA INCLUDED IN THE CORN BELT

The Corn Belt extends for about 900 miles from the middle of Ohio into Kansas and Nebraska, varies in width from 150 to 300 miles, and contains about 150,000,000 acres. It includes a small corner of Michigan, the western half of Ohio, the northern two-thirds or thereabouts of Indiana and Illinois, practically all of Iowa, most of that part of Missouri lying north of the Missouri River, a narrow strip along the northern boundary of Kansas extending almost to the western limit of the State, eastern and southern Nebraska, southeastern South Dakota, and southwestern Minnesota. Within its boundaries the average production of corn, according to O. E. Baker, is in excess of 3000 bu. per sq. mile.

Its fitness for corn is the result of the combination of a humid, almost tropical, summer climate, having the hot nights which that grain requires, with rich, level land, nearly all easily cultivated by machinery which holds the labor requirements of corn culture down within reasonable limits.

Cold, dry winters are an advantage to those parts of the Belt where they prevail, as they lessen the leaching of the soil.

The center of American industry is now near Columbus, Ohio, while roughly two-fifths of the entire population of the United States is within 650 miles of Burlington, Iowa, the approximate center of the Corn Belt. Its location with regard to export markets is by no means so satisfactory as it is for home markets, and there is no doubt that this territory has suffered from this cause under the advance in freight rates, which began in 1918 and ended in 1921.

A FAVORED SECTION OF TEMPERATE ZONE

Everything considered, the American Corn Belt is probably the richest and best-farmed large area of the temperate zone.

The low point of most Corn Belt prices was reached in 1921. The change from animal to mechanical transport in cities and the use of the tractor on farms have greatly reduced the demand for the kinds of feed consumed by horses and mules, the Secretary of Agriculture having estimated in his report for 1927 that from 15,000,000 to 20,000,000 acres of crop land have thus been released for production for other purposes. It seems certain that in course of time the gain in urban population at the expense of that of the countryside will reach a point where the larger production per worker on the land will not offset the shift of population cityward and domestic demand for foodstuffs will begin to creep up on supply. The general increase of population is, of course, operating steadily in this direction. —E. M. Miller, in *Commerce Monthly*.

Prizes for Paper on Silent Gearing

ANNOUNCEMENT was made at a meeting in January of the Société des Ingénieurs de l' Automobile, in Paris, that Vice-President Waseige, of that Society, had offered a first prize of 2000 francs, and a second prize of 1000 francs, to be awarded for the most interesting paper incorporating practical suggestions for attaining relatively quiet-running conditions in automobile transmission mechanisms, or indicating manufacturing methods for the purpose.

The competition is open to everybody, without regard to nationality. Two copies of every paper submitted should be in the hands of the Secretary of the Society, at 8 Rue Jean-Goujon, Paris, VIII, France, before April 1, 1929. Manuscripts should be signed by a false name or numbered and accompanied by a sealed envelope containing the author's true name and pseudonym or number corresponding to that on the manuscripts. If the author is employed by a company making a product related to the object of the competition, he should show that he has been authorized by the company to participate.

Ignition Requirements for High-Compression Engines

By J. T. FITZSIMMONS[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

ADVENT of engines operating at higher compression and higher speed than engines used a few years ago in automotive vehicles has necessitated refinement of all engine accessories, including the ignition equipment. It is necessary that the ignition units give unfailing performance at top speed of the engine without sacrifice of long life of the units. Storage-battery ignition, with a generator as a source of energy, is used almost universally in this Country today, and is asserted to be the cheapest, simplest, easiest to service and most reliable system known for vehicles in which a storage battery is required for starting, lighting and other purposes.

The electrical circuit used in the ignition system of automobiles today is almost identical with that designed for the 1912-model Cadillac, which was equipped with the Delco electrical engine-starter, except for refinements and greater reliability. Development has been carried on to adapt the system to the more exacting requirements imposed by the high-compression ratios and at the same time to improve its performance at top speed of the high-speed engine.

Essential parts of the battery ignition-system are listed and the required mechanical and electrical properties of a system that will operate satisfactorily on present high-speed high-compression engines are described.

The author discusses the exactions imposed on the distributor by engine torsional vibration, the need of an automatic spark-advance mechanism in the distributor, the peculiar conditions in some engines caused by non-homogeneous mixture surrounding the spark-plugs, the difficulties arising from shrinkage of materials used for coil tops, rotors, and distributor caps during their manufacture, the characteristics of the primary and secondary currents, the influence of the high-compression engine on design of the distributor cam and circuit-breaker lever, construction of the ignition coil and the advantage of the high-inductance coil, and other related matters.

No attempt is made to predict the future trend in ignition, but belief is expressed that a device that will automatically advance the spark above full-throttle position when operating at low load with partly closed throttle would make possible a better carbureter-setting on part throttle and result in better fuel economy at car speeds between 15 and 50 m.p.h.

AS those connected with the automotive industry are well aware, the last five years in engine design has been a period during which a vast amount of development work has been done in an effort to raise engine compressions without introducing any characteristics which might prove unsatisfactory to the user. The foundation for this investigation was no doubt the result of the high price of gasoline existing at about the time this work was started, when fuel was selling at prices at least 50 per cent higher than those of today. About that time the public began to accept the performance of the automobile as fairly satisfactory, but, as a result of the high price of fuel, demanded an engine that would use less of it.

With the subsequent reduction in fuel price, increased prosperity of the Country, and the highly competitive condition of the automotive industry, the need for a more efficient engine as a means of saving fuel became less important, and design work was continued as a means of securing more power without increasing engine weight, so that the acceleration and top speed of the automobile in which this powerplant was used might be bettered. As ethyl gas and other doped fuels have come on the market, improvements in lubrication, combustion-chamber shapes, cooling, and engine balance have been made, resulting in higher compression-ratios and increased engine-speeds. This has brought about a refinement of all engine accessories, including the ignition equipment. It is necessary that satisfactory performance at top speed, without sacrificing long life, be obtained from the ignition units. Unfailing performance of this part of the equipment must be secured if the owner expects to receive continuous service from his automobile. Any breakdown of the ignition system immediately affects the operation of the engine, and roadside repairs cannot be made readily by the average driver.

Current from the storage battery, with a generator as a source of energy, is almost universally used in this Country today as a means of igniting the mixture in the engine cylinder. This system is rapidly replacing other types on the engines of European automobiles, and therefore will be the only system considered in detail in this paper.

Prior to the use of the electrical engine-starter, with the generator and storage battery necessary with it, battery ignition-systems were, for the most part, auxiliary units to be used only when cranking, when the voltage generated by the magneto was too weak to fire the mixture, or when the magneto failed. Dry cells were the source of power, consequently economical use of current was of prime importance, whereas accuracy of timing and the elimination of lag with speed were not regarded as essential. With the advent of the Delco starting system on the 1912 Cadillac, and the use of a storage battery constantly kept charged by a

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generator, a battery ignition-system was designed that had the necessary characteristics to give competitive performance with the magneto, an instrument regarded as standard for ignition at that date. The dry-cell system of ignition was carried during the following two or three years as an auxiliary on all cars using storage-battery ignition, but by 1915 the storage-battery type of ignition had become so dependable that use of the auxiliary dry-cell type was discontinued. Today, on all types of automotive engines in vehicles in which a storage-battery is necessary for lights, starting or other purposes, the storage-battery type of ignition is the cheapest, simplest, easiest to service and most reliable system known.

Strange as it may seem, the electrical circuit used on the ignition system of the automobile today is identical with that used on the 1912 Cadillac. Refinements and greater reliability of the units have been made to keep abreast of engine development, but fundamentally the functions of the units are the same as they were 17 years ago.

Essential Parts and Properties of a Battery Ignition-System

From the engineer's point of view, development has been carried along two roads simultaneously. It has not only been necessary to develop refinements that would take care of higher compression-ratios, but the top-speed performance had to be improved at the same time.

A battery ignition-system consists of the following essential parts:

(1) A generator or storage battery as a source of energy

(2) An ignition coil, consisting of a primary and a secondary winding on the same magnetic circuit

(3) A distributor, consisting of a set of contacts which are opened and closed by a cam and spring, the shaft driving the cam being customarily connected to the engine through a governor or an automatic-advance mechanism capable of advancing the position of the cam with respect to the engine drive as the speed increases; and a condenser connected across the contacts to reduce arcing as the primary circuit is opened by the contacts. The high-tension part of the distributor consists of a rotor or sweep, usually driven by the circuit-breaker cam, so timed that the high-tension current from the coil secondary, which is fed to it, is distributed through a series of radial contacts in the distributor cap to each engine cylinder at the proper time, a secondary impulse being transmitted from the coil whenever the primary circuit is broken by the contacts of the circuit breaker

(4) The necessary connections and switch to make the circuit complete

To operate satisfactorily on our present high-speed high-compression engines, the battery ignition-system should have the following properties:

(1) The distributor should have sufficient mechanical strength to withstand sudden acceleration and deceleration and also all torsional vibrations transmitted from the engine through the distributor drive

(2) The distributor automatic-advance mechanism should be designed so as to hold the spark advance with speed within reasonable limits, and at the same time be free from objectionable noise at low speed and from hunting if the engine rolls

(3) Mechanical design of the distributor should enable it to hold the synchronism of spark from engine cylinder to engine cylinder within reasonable limits, yet have manufacturing tolerances which will not be impossible to hold, and parts which will be sufficiently rugged to function satisfactorily as long as other vital parts of the automobile

(4) The distributor circuit-breaker cam, circuit-breaker lever and spring should be designed so as to be comparatively free from noise and at the same time have no pronounced frequency of vibration over the entire engine range, which might interfere with the spark

(5) Insulation for the high-tension or secondary part of the distributor should be rugged enough to withstand shipping and handling, and be designed so as to withstand the effect of corona throughout the life of the car

(6) Coil and condenser should have sufficient insulation and be designed electrically to give sufficient spark at the plugs when cranking under low voltage, at normal voltage and maximum compression during acceleration, and at top engine-speeds. Constants of the circuit must be such as to give no objectionable arcing or burning of the distributor contacts under normal operating conditions of the car

Effect of Engine Torsional Vibration on Distributor

A distributor for a slow-speed engine, particularly if the automatic-advance mechanism is omitted, is not a difficult unit to design. The speed is only one-half that of the engine speed, so no problem is involved. With the high-compression engine and the increased speeds, other factors enter. The effect of engine torsional vibration upon the distributor was first impressed upon me during the World War at the time development work was being done on the Liberty aircraft-engine ignition. The problem seemed to be fairly simple with a non-automatic distributor driven at comparatively low engine-speeds, the factor of prime importance apparently being that of keeping the weight down. As soon as experimental engines were put on tests, however, we found that equipment designed to automobile standards was hammered to pieces in a few hours by the torsional vibration transmitted from the engine, in which parts were made light and flexible without reference to vibration. By experience we learned that, even in the ignition distributor, only the best material and design would take this punishment, and the success of the equipment on this engine during the war and in commercial fields for the years following, is indicative of the lesson learned.

Only in the last three years, with the development of the high-compression high-speed engine, has it been necessary to give this matter consideration on automotive equipment, Of late years we occasionally try out a standard-distributor design upon some new engine and find that it fails to give satisfactory service. In such case an investigation will show that the drive gear of the distributor may wear excessively in three places 120 deg. apart. Automatic-advance parts may

wear when operated at a critical speed of the engine, since the periodic vibration is transmitted to them and causes them to oscillate continuously. This condition makes it desirable to design parts of the distributor so that they will have the least possible inertia and to have rotating parts symmetrical so that their rotating balance will not be affected. As a result of conditions found in present engines, the manufacturer of ignition apparatus has been forced to improve his standard line of equipment so as to take care of this condition wherever it may occur.

Automatic Ignition-Advance Mechanism

An automatic-advance mechanism, to advance the time of ignition with respect to engine-piston position, is now regarded as an essential part of the ignition distributor for the modern passenger-car engine. This feature is also becoming popular on motorcoach and truck equipment. The distributor automatic-advance mechanism must be positive in action and free from friction. The design must be such as to allow reasonable changes in the advance curve without extensive retooling. The usual high-compression engine is very sensitive to spark position. Changes in compression ratio, combustion-chamber shape, spark-plug location, carburetion, or inlet-manifold design may make a considerable change in the slope and range of the advance curve. These details may be settled by the engine manufacturer only a few days before going into production, thereby necessitating last-minute changes in the advance curve of the distributor. In our factory production-line today, we are building distributors to more than 50 different curves. As a rule, high-compression engines have curves with less maximum range, consequently the tolerance must be held closer. A tolerance of 5 engine degrees at some definite engine-speed might not be important on an engine the total advance of which is 40 deg., but would be too great for an engine the total advance of which is only 15 deg. Fig. 1 indicates some of the various advance-curves used on different production engines today. Because high-compression engines have a tendency to knock under full load, there has been a gradual tightening up in the limits allowed on the distributor automatic-advance.

Peculiarities Due to Non-Homogeneous Mixture

In this connection, it may be well to cite some of the peculiar conditions experienced occasionally on some engines. This phenomenon apparently is due to a non-homogeneous or stratified-mixture condition around the spark-plug at certain speeds. Such engines will require the nominal spark-advance with speed up to a certain point, at which time the engine will miss slightly, or exhaust from the various cylinders will appear non-uniform. Retarding the spark may eliminate miss without any apparent increase in power, indicating that the advanced position of the spark is the correct one, as the engine power is as great with a slight miss as it is with the retarded spark without miss. Such an engine may fire smoothly at the critical speed if the voltage on the ignition system is increased, although but slight increase in power will be indicated. This increased voltage is necessarily a rather severe overload in the ignition system. A check usually will show that the smoother performance of the engine is due to the longer time-duration of the secondary spark. If this spark lasts long enough, a time will come when the mixture around the spark-plug is combustible and consequently is ignited. The effect is the same as if the spark were actually retarded. Engines having characteristics such as these often have a tendency to miss on rather high-speed idle, since they may not scavenge well when only a small amount of mixture is fed into the cylinders. Close cooperation of ignition, carbureter and engine manufacturers is necessary to work out these problems to a satisfactory conclusion.

A non-homogeneous mixture, which seems prone to occur in our high-compression engines, also manifests itself in other ways. We may find that an engine having the same compression as another of a different design requires a great deal more voltage at any given speed to fire across the spark-plug gap. The spark required may vary considerably from cylinder to cylinder on certain engines. Some recent tests indicated that a spark which would jump only a 0.06-in. gap in air would fire across the plug of one cylinder of a certain engine at a given speed and load while another cylinder with the same spark-plug setting required the equivalent of a spark to jump 0.19-in.

As additional requirements of the mechanical features of the distributor for high-compression engines, it is desirable that synchronism, or variation of the spark from the theoretical correct position from cylinder to cylinder, be as small as possible.

Shrinkage of Material of Parts

For ignition parts such as coil tops, rotors, and distributor caps subjected to high voltages, phenol-resin compounds are almost universally used. These compounds, in their initial state, become plastic when subjected to high pressures and temperatures, and can be produced economically on a production basis from polished-steel molds. If the molds are properly polished, a practically finished product results, it being necessary only to remove fins and to machine any metal inserts that may be desirable after molding.

The phenol-resin compounds used for this purpose contain wood pulp or other cellulose material as a filler, consequently they possess some of the physical characteristics of these fillers. At temperatures in excess of 200 deg. fahr., additional shrinkage after manufacture may occur, causing trouble with the mechanical fit of parts, these becoming tight or loose in service, depending upon design. It is therefore advisable to mount ignition parts containing this material as far as possible from the exhaust pipe, so as to reduce this difficulty. Where this cannot be done, it may become necessary to increase the initial size of the mold, then bake the finished part for a considerable time at high temperature until it has reached the proper size and most shrinkage has been removed. This discolors the part and tends to make it mechanically more brittle, although its electrical and insulating properties are not decreased. It necessarily increases the cost of the part, as it involves additional scrap and reoperation on those parts which fail to shrink to the correct size during the initial bake. At best, it is far from a desirable process, since the shrinkage varies considerably with the material and the molding conditions. Molds having special dimensions to allow for shrinkage must be made, which prevents standardization of tool

parts and the distribution of cost over a number of customers.

Factors That Affect Voltage Requirement

Voltage of the secondary current of an ignition system depends upon the amount required to produce a spark at the plug, the voltage rising until it breaks down the gap; consequently, the insulated parts of the circuit must be of sufficient capacity to take care of this. The voltage required to break down the gap depends upon temperature and compression of the mixture as well as the material, temperature and setting of the spark-plug electrodes. Other conditions remaining the same, the voltage required to jump the gap increases with compression and spark-plug setting. Higher voltages are therefore required with high-compression engines, and this is further increased by the tendency to set spark-plug gaps wide to secure better idling of the engine. This higher voltage imposes more strain on all the insulated parts of the system; consequently we are finding that designs which were entirely satis-

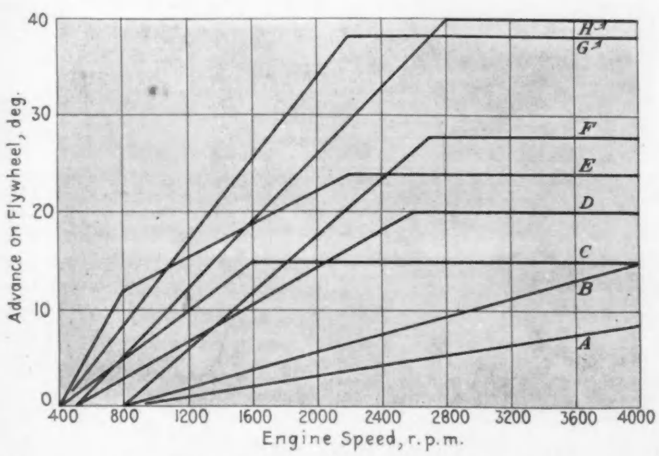


Fig. 1—Spark Advance Required on Various Passenger-Car Engines in Present Production

Because High-Compression Engines Have a Tendency To Knock under Full Load, the Limits Allowed on the Distributor Automatic-Advance Have Gradually Been Reduced. A Tolerance of 5 Engine Degrees at Some Definite Engine-Speed Would Be Too Great for an Engine the Total Advance of Which Is Only 15 Deg.

factory for the systems of private passenger-cars a few years ago do not have a sufficient factor of safety today. Although having sufficient strength as regards creepage distance and instantaneous voltage, they fail in long-continued service. Unless enough material is used and the design is carefully worked out, the effect of the corona and the continued dielectric stress eventually will cause a failure. In addition to laboratory endurance tests, our proving ground for this is the motorcoach service, in which the high-compression engines have a high load-factor and are operated more hours per day. We have had insulating material fail within two months on motorcoach equipment, while the same equipment on a passenger-car in large production gave satisfaction throughout the life of the car.

Design of Cam and Breaker Lever Influenced

The high-compression high-speed engine also has had its influence on the design of the cam and the circuit-breaker lever of the distributor. At 3000 r.p.m. of a six-cylinder engine using a six-lobe distributor cam, the contacts are opened and closed 150 times per second, remaining each time on contact for approximately 0.004 sec. At 4500 r.p.m. of the engine the time interval has been reduced to 0.0026 sec. During this interval the contacts are together; they must make intimate contact without chatter, as this would interfere with the flow of current through them, thus causing a weak spark at the plug or even a complete miss at high speed. This breaker mechanism must make and break perfectly, approximately 10,000 times per car-mile if the engine is to run smoothly, or 1,000,000 times in 100 miles. Under average conditions, a car should run at least 10,000 miles without the contacts needing adjusting, which means that the distributor contacts have closed and broken the electrical circuit at least 100,000,000 times. It is not unusual for a driver to get 15,000 miles, or 150,000,000 operations, without adjustment. At top speed, on an American eight-cylinder car having two plugs to each cylinder, the two circuit breakers must break the primary circuit of each coil 280 times per second. Five hundred and sixty sparks per second are fed into the distributor from the ignition coils, are sorted into pairs, and sent to the spark-plugs in each cylinder in the proper order at the correct time. If they fail to do this, the performance of the engine becomes noticeably rough.

The foregoing figures are given to indicate that more is involved in this breaker mechanism than a pair of contacts, one of which may be fastened to any kind of a lever. The lever to which the movable contact is mounted must be rigid and light. It must be free from any period of vibration within the engine speed-range, and should operate without objectionable noise. Sufficient tension must be supplied through the spring which holds the contacts together, yet this pressure must not be so great as to cause excessive wear on the rubbing block, which is that part bearing against the cam. It might be well to state in this connection that lubrication of the circuit-breaker cam is becoming more and more important, as speeds increase and as the operating temperature of the distributor has been raised. A wear of 0.005-in. on the rubbing block of a distributor may cause erratic ignition, so it is essential that the wear be kept as low as possible.

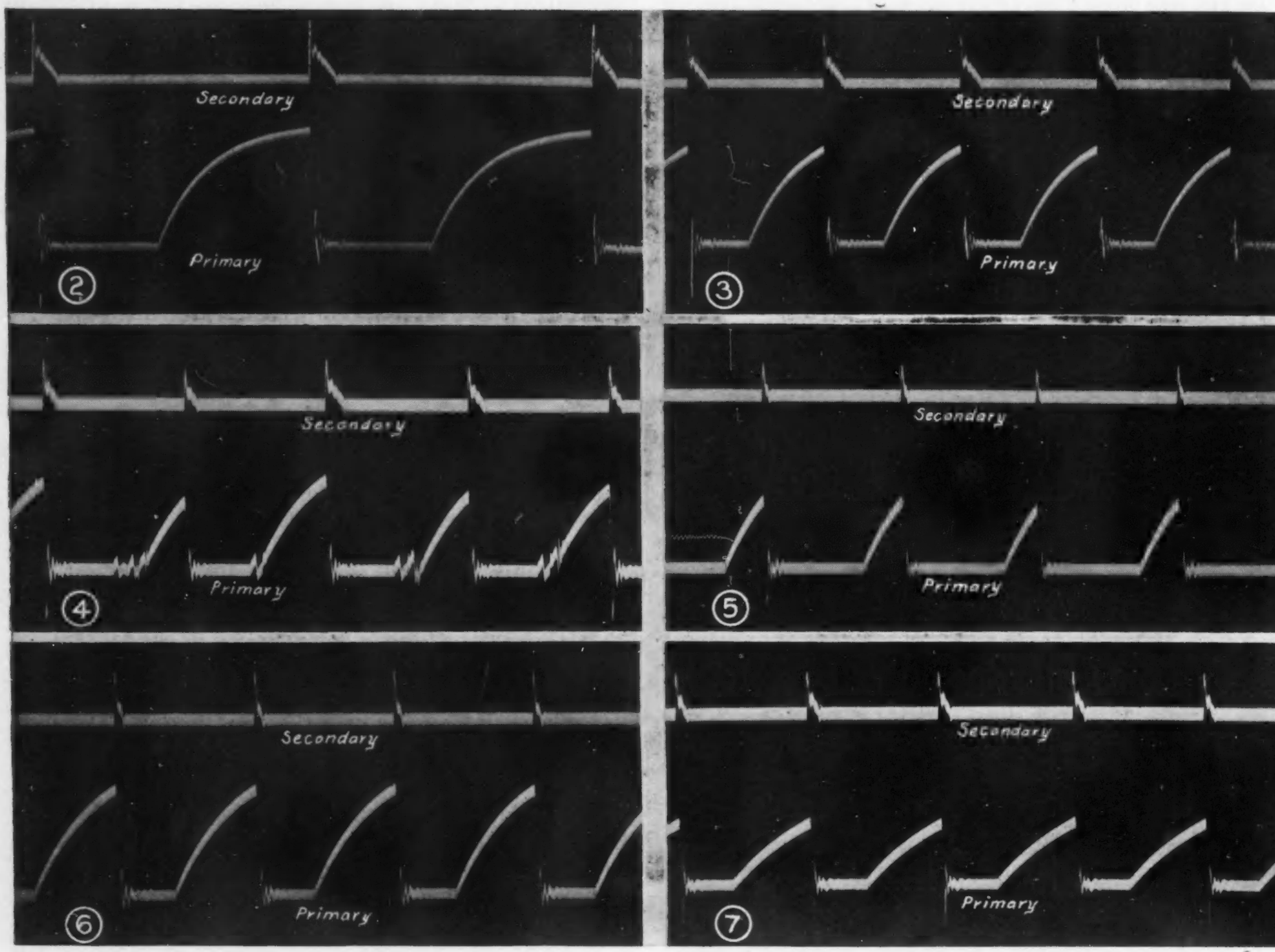
Oscillograph Studies of Circuit-Breaker Action

Cam design must be carefully worked out so that the circuit breaker rises smoothly and is lowered without unnecessary speed, otherwise lever chatter and objectionable noise will result. Study of the action of circuit-breaker mechanisms is made by the electric oscillograph. Fig. 2 indicates the primary and the secondary currents in an ignition circuit operating normally at slow speed. Fig. 3 shows the same circuit operating at twice the speed. Fig. 4 is the same as Fig. 3 except that a poor breaker-mechanism having circuit-breaker-lever chatter was used. The ragged appearance of the primary wave indicates that the contacts rebounded a number of times after coming together. By comparing the secondary current in Figs. 3 and 4, the effect of inferior breaker mechanisms upon the secondary current can be noted.

The cam and lever constants are also responsible for the distinction between the single and the two-lever distributors. As heretofore mentioned, the spark intensity in a given ignition system will depend upon the

value of the current that is broken by the primary. The value of this current depends upon speed, as indicated by Figs. 2 and 3, and upon the performance of the breaker mechanism, as indicated by Figs. 3 and 4. It may also be influenced by the cam design, as shown in Figs. 3 and 5, the latter oscillogram being identical with the former except that the contact angle is much reduced as a result of cam design and contact separation.

It may be well to mention also, that, to reduce to the minimum the chance for error in manufacture, we endeavor to design equipment so that a standard contact-separation and spring-tension give best performance. All conditions tending to shorten the time the distributor contacts are together reduces the primary current in the coil, this being a result of the time required for the current to build up in an inductive circuit. We believe that about 20 cam degrees are necessary to open and close the lever on our distributors as designed for high-speed engines. On a six-lobe ignition cam as used on a six-cylinder car, we can thus have a maximum closing time of 40 deg., which seems ample for present engines with the 6-volt three-cell storage battery as a source of current. On an eight-lobe cam, this is reduced to 25 deg., which we believe gives the ignition circuit insufficient time to build up voltage for satisfactory ignition on high-speed high-compression engines. By using a four-lobe cam with a separate breaker for each set of four cylinders, it is possible to obtain a contact angle of any amount up to 70 deg., if necessary, when two ignition coils are used. If used with a single coil, however, a maximum of only 40 deg. of contact can be used, otherwise the primary circuit will be made through one lever before the secondary spark has finished the discharge caused by the break of the primary through the other lever. With two breaker-levers, a single coil and a cam having four lobes, the same speed can be obtained as from a six-lobe cam and a single lever. Fig. 8 illustrates a standard six-lobe-cam six-cylinder distributor. A four-lobe-cam single-coil



OSCILLOGRAPH RECORDS OF ACTION OF DISTRIBUTOR CIRCUIT-BREAKER MECHANISMS

Fig. 2—Primary and Secondary Currents in a Circuit Operating Normally at 1750 R.P.M. of the Engine; 0.15-In. Spark Gap

Fig. 3—Same Circuit as in Fig. 2, Operating at Twice the Speed—3500 R.P.M. of the Engine; 0.15-In. Spark Gap

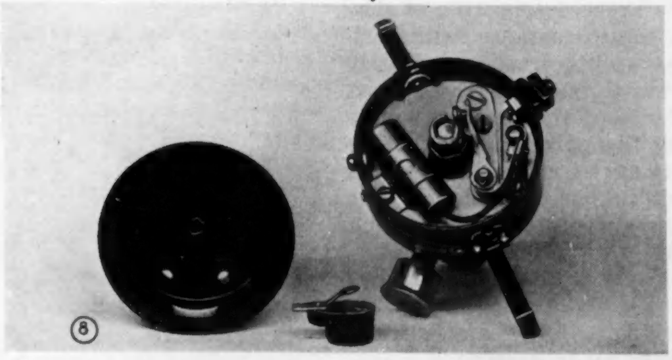
Fig. 4—Same Circuit, Engine Speed and Spark Gap as in Fig. 3, but Using a Poor Breaker-Mechanism Having Circuit-Breaker-Lever Chatter

Fig. 5—Circuit, Engine Speed and Spark Gag the Same as in Figs. 3 and 4, but with Contact Angle Reduced as a Result of Cam Design and Contact Separation

Fig. 6—With a Spark Gap of 0.30 In. Instead of 0.15 In. as in Fig. 3, the Circuit and Engine Speed Otherwise Being the Same, the Effect Is To Shorten the Duration of the Secondary Discharge

Fig. 7—With Coil Inductance Double That in Fig. 3, Other Conditions Being the Same, the Effect on the Primary Current and the Secondary Discharge Is Obvious by Comparison with Fig. 3

eight-cylinder distributor is shown in Fig. 9, and a four-lobe-cam two-coil distributor in Fig. 10. Fig. 11 shows another model of the last type as supplied for one of the newer high-speed eight-cylinder cars. Fig. 12 illustrates a two-coil dual-eight, supplying ignition for an engine having two spark-plugs per cylinder.



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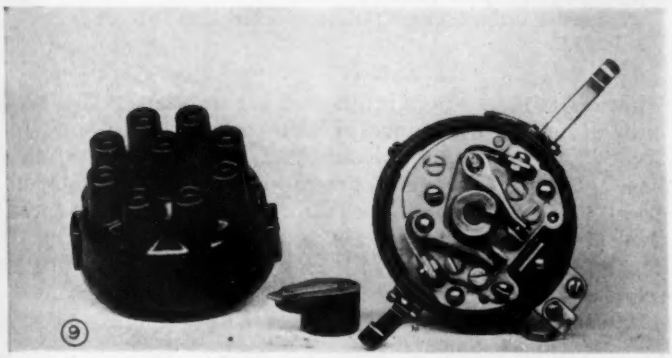

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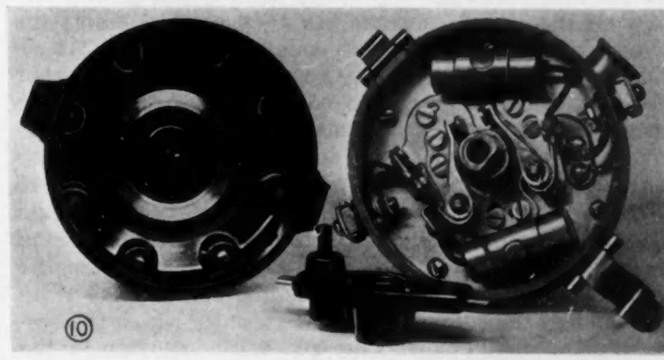

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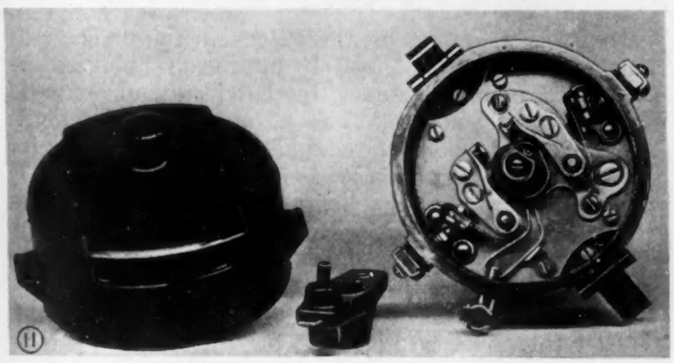

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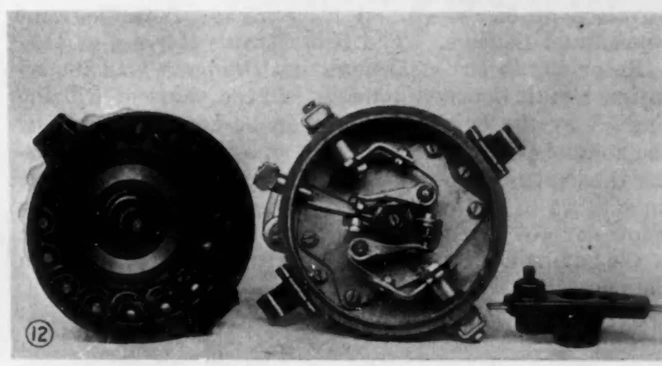

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Various Types of Ignition-Current Distributor

Fig. 8—Six-Lobe-Cam Single-Coil Single-Lever Distributor
Fig. 9—Four-Lobe-Cam Single-Coil Double-Lever Distributor
Fig. 10—Four-Lobe-Cam Two-Coil Double-Lever Distributor
Fig. 11—Four-Lobe-Cam Two-Coil Double-Lever Distributor with Special Cam and Cap
Fig. 12—Eight-Lobe-Cam Two-Coil Double-Lever Distributor for Dual-Plug Eight-Cylinder Engine

I feel that this paper would be incomplete without some reference to the other units involved in the ignition system. The constants of the circuit must be made so that it will supply not only satisfactory ignition for top speed but sufficient spark to strike across the plugs when cranking with low battery-voltages and poorly vaporized mixtures. On the other hand, current through the primary must be kept low enough in value to avoid causing oxidization of the circuit-breaker contacts at ordinary speeds in the cold weather, when the internal resistance of the battery is high and the voltage during charge is consequently greatly increased. Too much current through the contacts as a result of this condition, increased perhaps by poor connections and corroded battery-straps, forms non-conducting oxides at the surfaces of the distributor circuit-breaker contacts, which may make starting difficult if not impossible. Vapor from the crankcase collecting on distributors so mounted will add to the difficulty. Although I feel that about 75 per cent of the cleaning of distributor contacts to put ignition systems in operating condition is unnecessary, it is a fact that real trouble will result if the resistance, inductance and capacity of the circuits are not carefully worked out. The contacts are, after all, the limiting factor of our present ignition systems. When we find some alloy or metal that will carry 50 per cent more current without oxidation or other injury, a completely new field in ignition development will be open.

The condenser connected across the contacts should have sufficient capacity to assist in suppressing the arc, but must not be so large as to rob energy from the system and thus reduce the spark at the secondary. It must be so designed or located as to be uninfluenced by moisture, and must withstand the temperatures to which it may be subjected when mounted in the distributor, for this is the preferable location for it.

Importance of the Ignition Coil

The ignition coil also is one of the most important units in the system. To keep the efficiency high, iron losses must be kept small and the magnetic coupling between the primary and the secondary must be close. Iron-clad coils with the secondary next the core and with the primary wound on the outside have come into almost universal use. The construction is rugged, and

the core is economical to build. The small-diameter secondary reduces to a low value the loss from capacity between layers, while the outside primary affords enough radiating surface to prevent overheating at slow speeds or on standstill. The total resistance in the primary circuit of the ignition coil is rather definitely fixed, as this limits the current through the contacts at low speeds where the inductance of the primary exerts no great influence in holding the current down. This means the I^2R loss of the primary is virtually the same on all coils and, if a resistance unit is used, the number of watts radiated by the primary of the coil is much reduced. Although the windings of coils having resistance units operate cooler, the unit is rather easily damaged.

In a given coil-design, increasing the ratio between the primary and the secondary by increasing the secondary turns will increase, up to a certain point, the length of gap which the secondary will jump. Above this point no increase will be found, on account of either the decrease in efficiency in coupling as a result of the increase in length of the magnetic circuit or the increased capacity due to the great number of secondary layers. Since the energy in the secondary is equal to $\frac{1}{2} LI^2$ less the losses, where I is the primary circuit and L is the primary inductance of the circuit, increasing the spark length by change of ratio will decrease the time duration of the spark from the secondary. With a given coil, the wider the gap is through which the secondary discharge must take place, the shorter is the duration of discharge. A comparison of oscillograms reproduced in Figs. 3 and 6 illustrates this.

Referring to the statement that the energy in the ignition circuit depends upon $\frac{1}{2} LI^2$, the value of L being limited by the current which can be safely carried by the contacts, it will be seen that one method of increasing the energy is to increase the value of L, the primary inductance of the coil. This, however, is effective only below certain speeds, depending upon the contact angle of the cam, since the value of the current I depends upon the equation

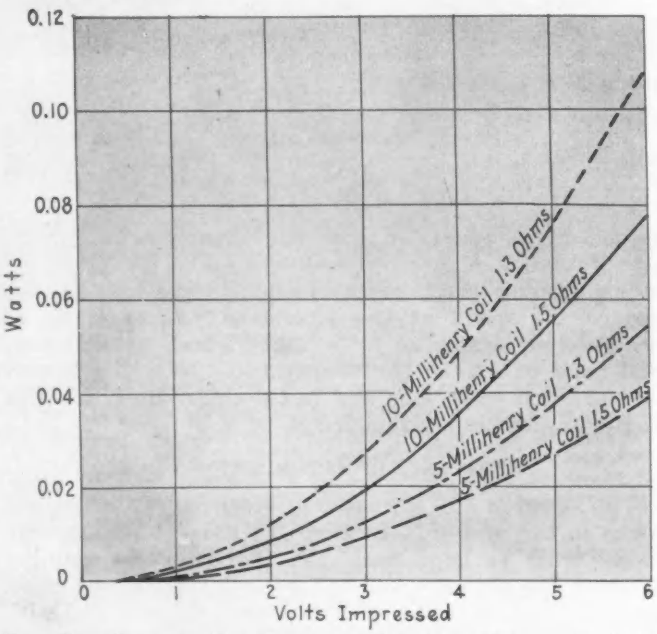


FIG. 13—POSSIBLE VARIATION OF PRIMARY ENERGY IN IGNITION COIL WITH VARIOUS VOLTAGES, CIRCUIT RESISTANCES AND COIL INDUCTANCES

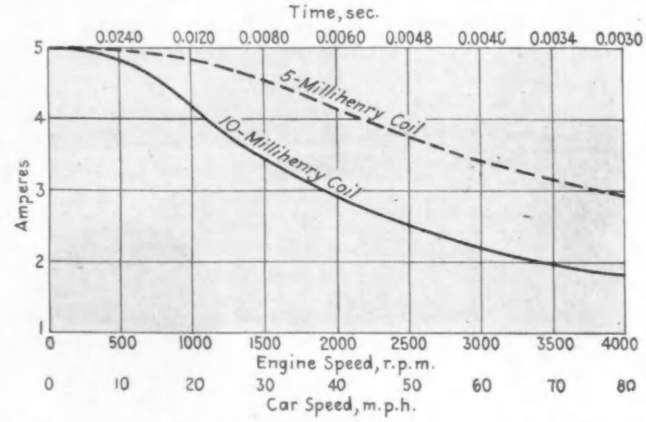


FIG. 14—PRIMARY CURRENT POSSIBLE IN THE IGNITION CIRCUIT AT VARIOUS ENGINE-SPEEDS AND COIL INDUCTANCES

$$I = E/R \ (1 - e^{-Rt/L})$$

where E is the voltage impressed across the ignition circuit, R is the resistance of the circuit, t the time in seconds the contacts are together, and e is 2.718, the base of the Naperian system of logarithms. Upon cranking when the voltage is low, it is desirable to have the value of L large, since t is so large, the value of I depending upon E/R. At high speeds, however, with a relatively high inductance, the value of t and also of I is small, consequently the value $\frac{1}{2} LI^2$ is small.

ADVANTAGE OF HIGH-INDUCTANCE COIL

Curves in Fig. 13 show the energy in the primary of ignition coils having 5 and 10 millihenrys inductance, 1.3 and 1.5 ohms resistance, in the circuit, under various impressed voltages. The advantage of the high-inductance coil under these conditions, in spite of its disadvantages at high speed, as shown in Figs. 3 and 7, will be noted, the energy being reduced as the voltage is decreased or as resistance is added to the circuit. These are the handicaps under which battery ignition must operate during the cranking operation by the electric starting-motor if poor connections exist or if the internal resistance of the storage battery is high as a result of sulphation or of low temperature.

In Fig. 14, the dotted line indicates the value reached by the current in the circuit having the 5-millihenry coil, 1.5 ohms resistance and $7\frac{1}{2}$ volts impressed, at various times of contacts or approximate engine-speeds, a six-lobe-cam six-cylinder distributor being used. The full line in Fig. 14 indicates equivalent results when a 10-millihenry coil is used. The dotted line in Fig. 15 illustrates the total energy put into the 5-millihenry coil at various speeds, while the full line is the result obtained with a 10-millihenry coil. These are all calculated curves, but a study of them shows why a high inductance is desirable at slow speeds while a low-inductance coil is necessary at high speeds.

The effect of coil inductance can also be seen in the oscillograms in Figs. 3 and 7, where conditions are identical except that the coil inductance in Fig. 7 is twice that of Fig. 3.

Most references in curves and oscillograms have been made to the primary circuit of the coil and the amount of energy it is possible to supply to it. This has been done for clearness, since the energy in the coil secondary which supplies the spark to the plug bears a rather direct relation to the primary. A previous ref-

erence has been made to the effect of the length of spark-plug gap on the duration of the secondary spark. Figs. 3 and 6 illustrate this difference if the plug gap is increased from 0.15 to 0.30 in.

Fortunately, on high-speed engines, it has not been necessary, up to the present time, to reduce the energy of the spark on cranking materially below that obtained from the low-efficiency high-inductance coils used on the slow-speed engines of a few years ago. The reason for this is that the over-all efficiency of the coils has been improved and that two-lever distributors, such as shown

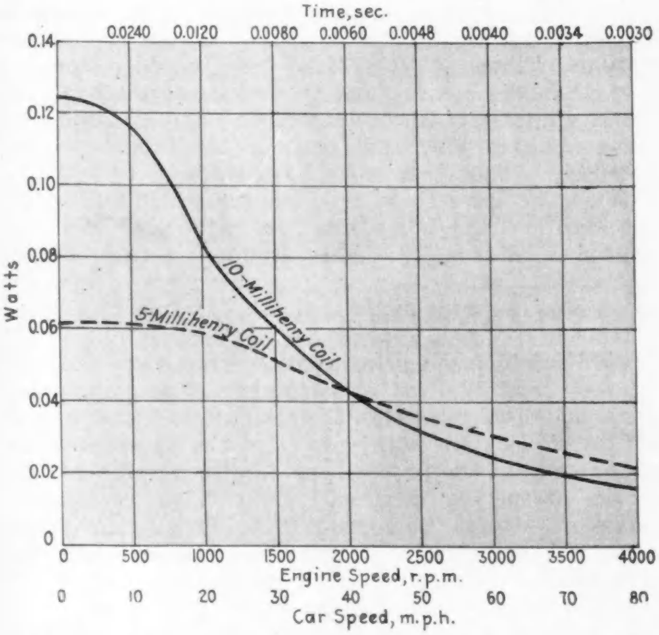


FIG. 15—PRIMARY ENERGY POSSIBLE IN THE IGNITION CIRCUIT AT VARIOUS ENGNE-SPEEDS AND COIL INDUCTANCES

in Figs. 9, 10 and 11, have been made. The longer contact-angle increases t in the equation

$$I = E/R\ (1 - e^{-Rt/L})$$

consequently a larger value of L can be retained.

In closing, I shall not attempt to predict what the future trend in ignition will be. On high-compression engines, only a very small amount of spark advance can usually be carried at wide-open throttle, if the minimum amount of spark "ping" is allowed. Since the average driver insists on carrying the hand-control of his spark all the way advanced, the car manufacturer times the spark so as to give the best operation on full throttle with the spark-lever in this position. With high-power engines, the load factor is rather low below a car speed 50 m.p.h. At low loads or partly closed throttle, the compression of the engine is greatly reduced, consequently a much greater advance of spark could often be carried advantageously. Since the driver cannot advance the spark above full-throttle position at partly open throttle, and would not if he could in most cases, I believe that a device to do this automatically has a certain field. It would not only make possible a better carbureter-setting on part throttle, but would also result in better economy between 15 and 50 m.p.h. car speed.

If engine compression is further raised and speeds increased, additional changes may be necessary. Ignition equipment has been made for and successfully operated on high-speed racing engines, but it has not been a design that would give satisfactory service over long periods when the car is run at moderate speeds. Suffice to say, ignition can be made to meet higher-speed conditions but whether this will be secured by increasing the primary voltage, by the use of a better contact-material, by lower-inductance coils with special starting devices or by a new and more complicated electrical circuit, only time can tell.

THE DISCUSSION

P. J. KENT[2]:—As an electrical man I believe I can criticize the ignition, while a carbureter man cannot do so without being accused of "passing the buck." First, I want to compliment Mr. Fitzsimmons on his paper, in which he has covered the subject in a very complete way. However, I wish he had covered the subject in a less general way and gone into more detail on certain parts of it. With all that he says on the ignition requirements of a high-compression engine, why do we not have ignition that will run an engine 5000 miles without giving trouble?

In the latter part of his paper I think that Mr. Fitzsimmons hit on the keynote of something that has to be taken more seriously today than it has been heretofore. I know that the ignition engineers have recently started some real research work on the subject. I refer to the contact points. As he says, everything hinges on proper operation of the contacts. After breaking the primary current you have to "make" contact again if you are going to continue to fire across the spark-gaps. It does no good to close the breaker points unless current flows across the contact. Conditions have arisen recently which indicate to me that a great deal of our ignition trouble is due to faulty contact at the breaker points, and I believe that much progress can be made by research work along this line.

In the paper a great deal was said about high-speed and high-compression conditions. I think Mr. Fitzsimmons is inclined to overestimate the seriousness of securing good ignition under high-speed and high-compression conditions, and to underestimate the seriousness of the troubles encountered at low speeds and when starting at low temperatures. I am not going to attempt to give a solution to this problem, but I hope we can get some real action from the ignition designers. Mr. Fitzsimmons remarked that better contact points could be used if the industry was willing to pay the price. It has been my experience that all of the ignition men say they are using the best contact points to be had. If he knows of anything that is better than what we have, I hope he will bring it out. I think I can induce our company, at least, to pay the price for it.

L. E. FOWLER[3]:—Will it be possible to improve the starting by making a separate starting-coil? If so, will it be worth the price? Also, does Mr. Fitzsimmons feel that the measurement of standardized spark-plug

[2] M.S.A.E.—Accessory and electrical engineer, Chrysler Corp., Highland Park Plant, Detroit.

[3] M.S.A.E.—Special experimental engineer, Oakland Motor Car Co., Pontiac, Mich.

gaps in an engine cylinder is sufficiently accurate to use as a check on manifold distribution?

Tungsten Best Available Contact Material

J. T. Fitzsimmons:—With reference first to Mr. Kent's remarks, it was said in the paper that we might have some more expensive way of getting the desired results; that is, by revising the whole circuit, putting many more parts in it, and perhaps making it cost four or five times as much as at present. We know of no better contact material than we are using today, which is almost pure tungsten, and we found out eight or nine years ago that the slightest impurity in it is serious.

About 75 per cent of the contact trouble is not contact trouble at all. If anything happens to the operation of an engine, the first thing a man does is to look at the ignition contacts. Most tungsten contacts look very bad under any condition. They do not necessarily have to look bright and smooth; in fact, very few of them do. If the contacts on 100 cars that are running all right are examined, it will be found that they look no better than the ones that are condemned; some of them may not look so good. I have been investigating a recent epidemic of contact trouble in one locality. We have not yet found the cause of it. The contacts that look the worst are the best. We use the same material in all cases. Customers are not reluctant in telling us when they are in trouble; but, so long as 90 per cent of them are not reporting trouble and are using the same contacts and ignition equipment, we think something else is involved in the other 10 per cent.

If contacts are run on a bench test, it cannot be shown that anything is wrong with them; but when they are put on the car sometimes something goes amiss. We do not always know what it is. We cannot always control it. We endeavor to investigate these complaints and correct the trouble.

As to Mr. Fowler's question about using the length of spark necessary to jump the gap in an engine as a check on mixture conditions, I have not run enough dynamometer tests to give a definite answer. We know, however, that with a given equipment we can run certain engines up to 4000 r.p.m. The same equipment may not run another engine 2800 r.p.m. without a miss. If the two-coil ignition was put in, we might go up to 3500 r.p.m. without trouble. More ignition on that particular engine seemed to give satisfactory power and operation.

Mr. Kent:—I agree that we cannot show anything wrong with the contact points on the bench test. Nevertheless, under actual car-operating conditions the troubles do develop in less than 5000 miles on a great many cars. I believe that the ignition-equipment manufacturers should investigate the metallurgical aspects of the breaker-point problem and not leave that entirely to the tungsten contact manufacturers, any more than automobile manufacturers leave all the ignition questions to the maker of the equipment.

Spark-Plugs Must Receive Attention

O. C. Rohde[4]:—The carbureter man blames the ignition man for engine trouble and vice versa; and when the two get together they both blame the spark-plug maker. While all of these men are here, I want to call attention to an item in connection with spark-plugs that all ought to know about. Lately there has been a great tendency in design toward the metric spark-plug. In the specification of a metric spark-plug the S.A.E. Handbook shows a 9/16-in. dimension from the gasket seat to the end of the shell. How that dimension got into the specification none of us has been able to find out. The original idea was to have the S.A.E. Standard agree with the international metric measurement, which is 12 mm. Since 1918 at least, all metric spark-plugs in this Country and in Europe have been ½-in., or 12 mm., which is slightly less; or ¾-in., which is the long type in the metric series. In the new engine designs, I hope all will take into consideration the fact that the spark-plugs in service throughout the world at present are ½-in. rather than 9/16-in. until the committee which has recently been appointed can definitely settle upon a final standard.

When we have these troubles for which sometimes the ignition and sometimes the carbureter men are blamed, I think a little more attention should be paid to the exact gap-setting of the spark-plugs so that the spark-plug may be eliminated as a factor of possible trouble.

We need to pay much attention, from both the carburetion and ignition standpoints, to the projection of the spark-plug through the combustion-chamber wall and to its location with respect to the valves and the piston; and to the proper type of plug for the normal service of the car in actual operation rather than to maximum engine performance in the dynamometer room. Another item is to make some allowance in the performance characteristics of spark-plugs during the first 500 miles of driving, the running-in period.

If more attention is paid to these items, I really believe we shall have much less trouble so far as the spark-plug is concerned and can definitely confine the trouble to either carburetion or ignition.

A Member:—Mr. Fitzsimmons mentions evidence of non-homogeniety of the mixture at various speeds in the high-compression engines. I think anyone who has done experimenting with cylinder-head designs, and any one who has explored for spark-plug conditions, has found the same thing. Have the ignition men ever made any oscillograms on a firing engine, and is it possible to do this? That is, do we know what the requirements are for starting combustion? Possibly a mixture that at one time has a high proportion of exhaust value may answer. Just what is the variation in the normal gap resistance in a running engine?

Mr. Fitzsimmons:—I have not made any tests in the last few years on that. Some years ago we started a test to find the effect of different mixture ratios on the amount of spark required to jump the gap and fire the mixture in the engine. Although these tests were not completed, our indications were that, with the particular engine used, when the carbureter was set to give the maximum torque, we required the least spark to fire the mixture. On enriching or leaning the mixture, we required more spark to jump the gap.

These were not accurate tests. They were made by putting a spark-gap in parallel with the plugs in the engine and noting how small this external gap could be reduced without causing spark to fail at the plugs. We found this setting varied from cylinder to cylinder, with mixture ratio, and throttle opening.

[4] M.S.A.E.—Chief engineer, Champion Spark Plug Co., Toledo, Ohio.

Electric Telemeter and Valve-Spring Surge

By W. T. Donkin[1] and H. H. Clark[2]

Annual Meeting Paper — *Illustrated with* Photographs, Diagrams and Charts

THE electric telemeter presents an excellent means for investigating the phenomenon of valve-spring surge. Basically, the telemeter is composed of two differentially connected stacks of thin carbon discs so arranged that, when the apparatus is subjected to strain, the pressure is increased on one stack and decreased on the other. Each stack forms one arm of a Wheatstone's bridge, and the resistances of the stacks vary with the pressure on them, thus slightly upsetting the balance of the bridge. If an oscillograph galvanometer-element be substituted for the usual bridging instrument, the arrangement will be found suitable for making photographic records.

To study valve-spring surge, the telemeter is connected across the points of a stiff C-spring, one end of which is held against the valve-spring in such a way that vibrations of the spring are transferred to the C-spring and thence to the telemeter. This equipment has made it possible to identify the cause of valve-spring surge as a resonant condition at certain speeds.

Except at low engine-speeds, the stress conditions of a spring having resonant points are much worse than is indicated by the conventional stress-formula, both as to degree and as to the rapidity of the stress cycle. Surge and stress conditions are improved by designing the springs for high frequency, and by making the pitch variable so that the frequency is variable as the valve lifts, thus eliminating resonance.

Discussion of this paper includes warnings in regard to lack of uniformity of valve-spring material and to the possible low-frequency of the electric telemeter, and suggestions for further study of fatigue as a cause of failure and of internal friction as a remedy for surge.

Further discussion on the subject of valve-spring surge is included with that of the Jehle and Spiller paper,[3] which was given and discussed at the same session of the Annual Meeting. The discussion of the latter paper immediately follows the discussion of this paper.

IT has been recognized for some time that valve-springs for poppet-valve engines come into resonance and vibrate freely in their natural periods at certain speeds within their operating range. This vibrational phenomenon has been designated as "surge." Surge points can be detected visually, as the vibrating spring has a fuzzy or blurred appearance, and audibly, because the vibrating spring emits a tone.

However, it is all but impossible to evaluate the magnitude of the surge by simple visual and audible detection, and to determine what happens when the spring seems not to be surging. To be of real value, a surge investigation should include some concrete record and should indicate what effect the surge has upon the stress conditions in the spring.

In this paper is presented the electric telemeter, with its auxiliary apparatus, as a means for making a thorough study of the operation of valve-springs, together with the results of some investigations made with it. By means of the telemeter, we obtain an oscillographic record of the operation of the valve-spring throughout its entire speed-range. Such an oscillogram consists of a series of valve-lift curves upon which are superimposed the wave-form of the free vibrations of the spring.

The electric telemeter was developed at the Bureau of Standards by Burton McCollum and O. S. Peters[4]. It has been improved and refined[5] and has had its field widened until it is now readily adaptable to many kinds of dynamic testing. The instrument can be seen in

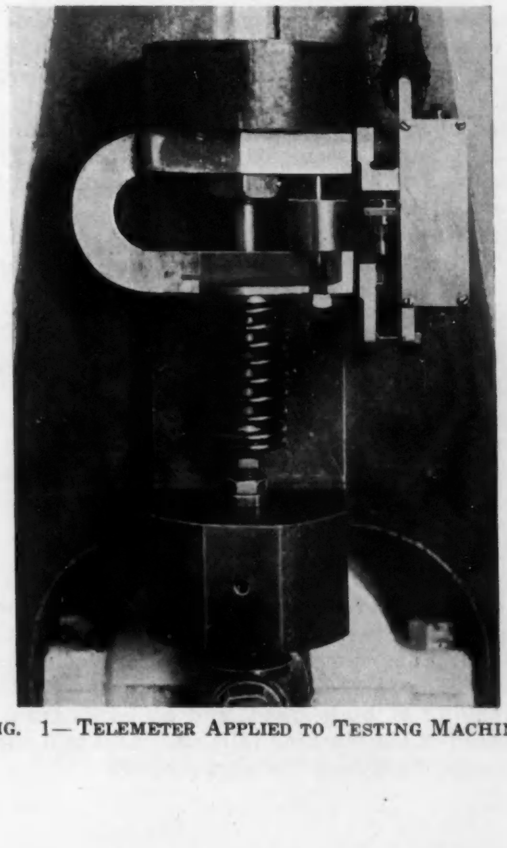


Fig. 1—Telemeter Applied to Testing Machine

[1] A.S.A.E.—Engineer, Cleveland Wire Spring Co., Cleveland.

[2] Engineer, Cleveland Wire Spring Co., Cleveland.

[3] See S. A. E. Journal, February, 1929, p. 133.

[4] See Technologic Papers of the Bureau of Standards, No. 247.

[5] See *Proceedings of American Society for Testing Materials* vol. 27, part II, 1927, p. 522.

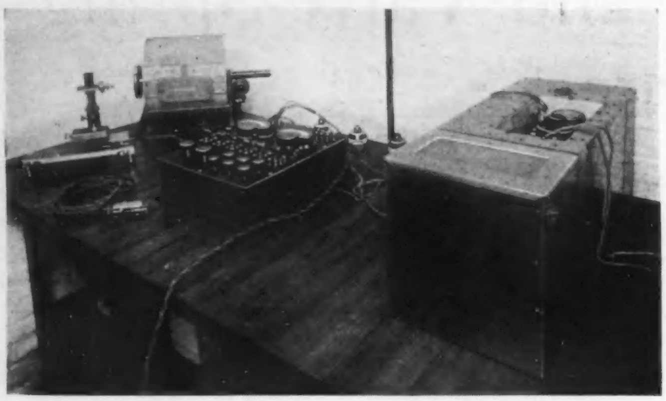


Fig. 2—Recording Apparatus of Electric Telemeter

Fig. 1, in the form in which it is used for the testing of valve-springs.

Construction of the Telemeter

Essentially, the telemeter consists of two differentially connected stacks of thin carbon discs so mounted in a frame that any displacement caused by vibration will increase the pressure on one stack and decrease the pressure on the other. Each stack forms one arm of a Wheatstone's bridge, and the current through the bridge instrument—milliammeter or galvanometer—varies as the pressure on the stacks is varied. This bridging instrument may be the galvanometer element of an oscillograph, in which case oscillograms can be made.

In addition to the telemeter itself and to the bridge, the apparatus consists of an oscillograph, a photographic drum and an oscillating-mirror mechanism. The last can be used with the oscillograph for visual inspection of the dynamic operation. This equipment is seen in Fig. 2.

The telemeter is used with the valve-spring testing-machine developed by our company and shown in Fig. 3, which consists of a shaft and a flywheel driven by an induction motor through a variable-speed transmission. The outboard bearing of the shaft is mounted in a cast-iron head upon which is mounted a block containing the valve-train parts assembled in their correct relation. The cam used to actuate the train is mounted on the extreme end of the shaft.

To adapt the telemeter to the work, a C-shaped spring was interposed between the valve-train block and the upper end of the valve-spring, as seen in detail in Fig. 1.

Operation of the Equipment

In operating the equipment, the valve-train testing-machine is started and adjusted to the speed at which observations are desired. The bridge is balanced and the telemeter gage properly adjusted beforehand. When the deflection, as shown by a milliammeter incorporated in the bridge, is adjusted to a convenient amount by either a range-changing plug or by varying the bridge voltage, a double-throw knife-switch is thrown to substitute the oscillograph element for the bridge milliammeter. An oscillogram can then be made, or the oscillating mirror can be driven at synchronous speed to give a visible standing wave. To record the whole range of operation, the motor current can be cut off with the machine running at high speed, and an oscillogram made as the speed of the machine falls off. This will show the entire range, including the surge points.

The drum for exposing the photographic film takes a film 36 in. long and 6 in. wide, and is driven by a sewing-machine belt from a speed-reduction unit. An interesting feature of the drum is an arrangement for axial movement, obtained by a worm and gear. When the drum switch is closed, a solenoid shutter opens; at the same time a magnetic clutch holds the worm-gear stationary so that the worm advances axially as it rotates. As a result, the wave motion has a slight lead across the film. By this means it is possible to obtain on a 36-in. film a record 12 ft. long, covering an elapsed time of 15 to 20 sec.

The electrical circuits of the equipment, including the telemeter, the Wheatstone's bridge, the light control for the oscillograph, the solenoid shutter for the drum, and the magnetic clutch which governs the axial motion of the photographic drum, are all shown in the diagram of Fig. 4.

Obtaining Quantitative Readings

By means of a comparator having a micrometer microscope, the telemeter gages employed can be so calibrated that each milliampere through the bridge can be related to a known deflection of the gages. The deflection of the gage is the deflection of the C-spring, which in turn is proportional to the deflection of the valve-spring. Hence the calibration provides a means of relating the amplitudes of the complex valve-lift curve to the actual dynamic stresses present at any instant.

One of the most important considerations of the method deals with the frequency of the C-spring. This must be high enough to prevent the spring from being

Fig. 3—Valve-Spring Testing-Machine

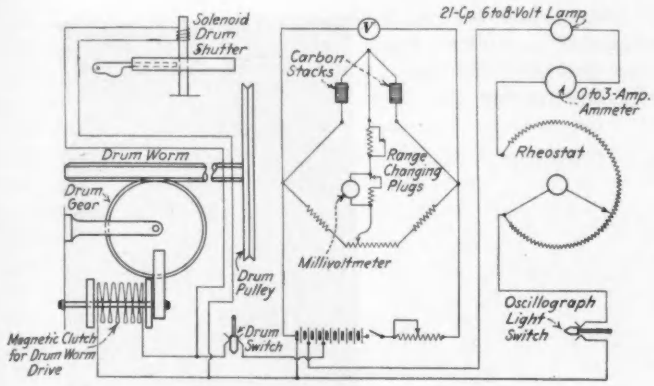


FIG. 4—DIAGRAM OF ELECTRIC TELEMETER

brought into resonance at any time. The C-spring finally developed deflects 0.001 in. under a load of 50 lb. This stiffness, with small mass, gives the C-spring a natural frequency of about 1000 cycles per second. This is too high to be observed on any of our records, and if present it can do no more harm than to introduce a high-order harmonic in the form of the spring-frequency wave. Means are provided also for damping this C-spring, when necessary.

The basic idea of the C-spring is that, as the valve-spring surges and the wave motion travels up and down the spring, the pressure at the top of the spring varies during every cycle of the wave motion. At one time this pressure is more than the normal static value, while at another time the pressure is less. This difference in pressure varies the deflection of the C-spring correspondingly, and its effect is thus transmitted to the recording apparatus by means of the telemeter gage. Since the normal full deflection of the C-spring will be only 0.001 in. when the difference between valve-open and valve-closed loads is 50 lb., the deflection-load curve is a straight line.

Another important item in a discussion of this method of testing valve-springs deals with the oscillograph galvanometer-elements. It must be admitted that the oscillograms do not and never can give a strictly true picture of the wave shapes encountered, because the galvanometer elements have a certain slight mass and inertia and therefore a period of vibration in themselves. However, any errors on this account will be negligible provided the elements are well damped and have frequencies high enough to produce no objectionable harmonics in the wave-form. In the case at hand the elements have frequencies of about 1200 cycles per second, which is sufficiently high for our purposes.

In making observations with the oscillograph, one element is used to obtain the complex valve-lift curve, while a second is connected in series with suitable resistance-units across the secondary of a bell-ringing transformer to obtain a 60-cycle alternating-current timing wave.

The Cause of Surge

Telemeter oscillograms, as shown in Figs. 6 to 20, are of material aid in the determination of the true cause of valve-spring surge. In using the oscillograms for this purpose it is important to investigate the operation at speeds which indicate both resonant and non-resonant conditions.

The points of resonance are the points with which we are most concerned, because they indicate the presence of harmonic forces which cause the spring to vibrate. Since spring frequencies ordinarily lie between 10,000 and 30,000 vibrations per minute, it is obvious that the harmonic forces exciting the spring must, to cause resonance at various speeds, have frequencies far in excess of the camshaft speed; yet these harmonic forces are definitely linked with the cam, because the cam is the agent by which they are set up.

Referring to the telemeter oscillograms again, it can be seen that at each resonant speed there is an integral number of vibrations of the spring per camshaft revolution. It can be further observed that the number of complete vibrations or waves per revolution times the resonant speed in revolutions per minute equals the spring frequency in vibrations per minute. This establishes the fact that for resonance, where there are n free waves per revolution, there must be acting an harmonic force which has a frequency of n times the fundamental or camshaft frequency.

At times the spring can be observed to be vibrating in halves at double its fundamental frequency, when the harmonic frequency of n times the resonant speed equals twice the spring frequency. The spring then seems to vibrate in much the same way as a vibrating string, in that it is capable of vibrating in either its fundamental frequency or its first overtone.

Undoubtedly, if there were present strong harmonic forces of higher order than those commonly encountered, the spring would vibrate in thirds as its second overtone comes into resonance with the harmonic forces. Actually, the spring can be observed vibrating in either its fundamental or its first overtone, or in its fundamental with the overtone superimposed. In other words, a resonant condition will result when $ns = NF$, where n is the order of the harmonic force; s is the camshaft or fundamental speed, in revolutions per minute; N is the order of the spring vibration; and F is the fundamental frequency of the spring, in vibrations per minute.

Resonant and Non-Resonant Harmonic Forces

The presence of harmonic forces can be accounted for by investigating the valve-lift curve throughout its complete cycle from one valve-open position to the next, considering the first valve-open position as 0 deg. and the second as 360 deg. Such a curve, which is continuous and symmetrical about the 180-deg. point, can be represented by a constant term and a simple trigonometric series. The solution of such a curve involves the evalua-

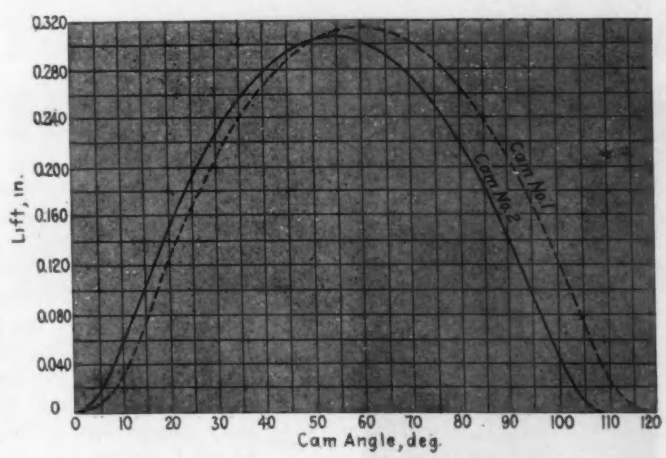


FIG. 5—LIFT CURVES OF TWO CAMS

FIG. 6—OSCILLOGRAM OF SPRING NO. 1 WITH CAM NO. 1, FROM 1750 TO 750 R.P.M.
Full-Size Detail Sections of This Oscillogram Are Shown in Figs. 8 to 11

tion of the coefficients of the various terms of the series, which coefficients indicate the amplitudes and signs of the various harmonics. Expressed mathematically, the series can be equated as follows:

$$f(y) = A_0 + A_1 \cos \omega t + A_2 \cos 2\omega t \ldots + A_n \cos n\omega t \quad (1)$$

where A_0 is a constant term, or the average ordinate of the curve; A_1 is the amplitude of the fundamental; A_2 is the amplitude of the second harmonic; A_n is the amplitude of the nth harmonic; t is the time, in seconds, and ω is the angular velocity of the fundamental, in radians per second.

The harmonic forces themselves are in reality acceleration forces, or the second derivatives with respect to time for the various terms of the above series. It is apparent, however, that these harmonic forces will always be proportional to A_n.

For the purposes of this paper, the two lift-curves of Fig. 5 were analyzed for harmonics, and the resulting values of the harmonics are listed in Table 1. The most interesting points in the two analyses are that the twelfth harmonic has a very appreciable value for the lift curve of cam No. 2 but a very low value for that of cam No. 1, and that the ninth harmonic has comparatively high value for cam No. 1 but has a very low value for cam No. 2.

OSCILLOGRAMS CHECK MATHEMATICAL ANALYSIS

It is not the purpose of this paper to dwell upon the mechanics of the harmonic analysis of the lift curve. This subject is treated in detail in the paper on Idiosyncracies of Valve Mechanisms[6], by Ferdinand Jehle and W. R. Spiller. However, it is important to note that the values of the harmonics as shown in Table 1 check in magnitude with the intensity of the surge at resonant speeds, as shown by the telemeter oscillograms. It is particularly interesting to note that, where the harmonic analysis gives a positive value for A_n, the free wave has a crest at the maximum-lift point; and, where the analysis assigns a negative value to A_n, the free wave has a trough at the maximum-lift point. This is interesting because, in analyzing the valve-lift curve for harmonics, it was assumed that harmonics which had an additive effect to the fundamental were positive, while those which had a subtractive effect were negative.

However important and interesting the surge points may be, the non-resonant speeds at points intermediate of the resonant points must not be overlooked. In studying the operation at non-resonant speeds, cognizance must be taken of the fact that resonance itself is a peculiar phenomenon. If the damping characteristics of the spring approach zero, the resonant speed for any harmonic will be very sharp and critical. In this case, at any speed between two resonant speeds the spring will not vibrate in its natural period, provided

[6] See S.A.E. JOURNAL, February, 1929, p. 133.

FIG. 7—OSCILLOGRAM OF SPRING NO. 1 WITH CAM NO. 2, FROM 1750 TO 750 R.P.M.
A Full-Size Section of this Oscillogram Is Shown in Fig. 12

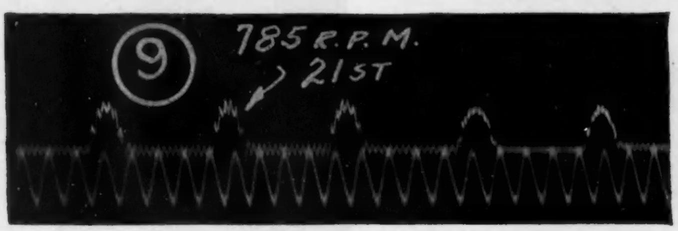
no higher harmonics are present which would tend to excite the spring. In the actual case, damping enters into the spring operation and alters materially the hypothetical case mentioned. Damping has the effect of flattening and spreading the resonance curve, so that the surge amplitude is large at speeds considerably removed from the resonant point in either direction.

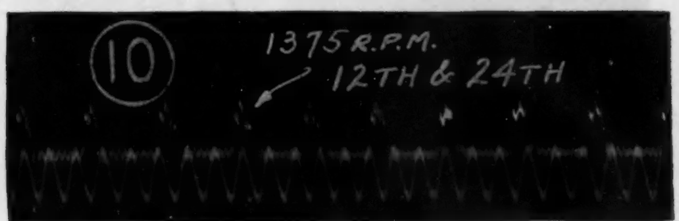
In further investigation of the actual case, let us consider a spring vibrating in response to a strong tenth harmonic. Assume also that there is a strong eleventh harmonic but no harmonic between the two, such as the twenty-first, which would tend to cause the spring to vibrate in halves. In the case thus set up, the spring would respond vigorously to the tenth; and, if the camshaft speed be permitted to drop, the surge amplitude would tend to decrease because of the damping characteristics of the spring. During this period of surge decrease, slightly more than 10 free waves elapse between valve lifts, so that the wave motion from the preceding lift arrives somewhat out of phase. This gives rise to a slightly interfering effect and decreases the surge slightly.

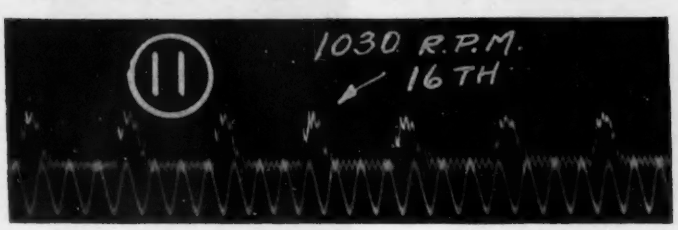
The maximum interference is obtained when $10\frac{1}{2}$ waves elapse between valve lifts, because then the wave motion from the preceding lift arrives exactly one-half wave out of phase. As the speed decreases beyond this point, slightly more than $10\frac{1}{2}$ waves elapse between valve lifts, the interference is less, and the surge amplitude builds up. As the speed further decreases, the interference effect is lessened until a point is reached at which there are 11 complete waves between lifts. At this point the wave motion is again in phase, and we have another point where the surge-amplitude is a maximum.

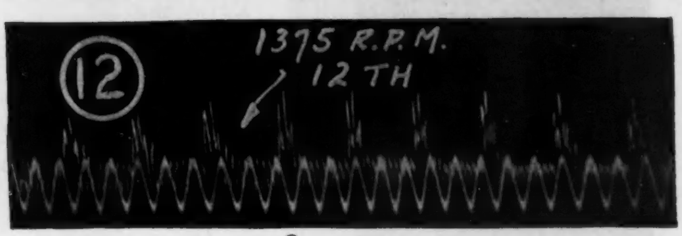
If we further extend this supposition to include the operation of the spring from a resonant speed influenced by a weak twentieth harmonic to the next resonant speed due to a weak twenty-first, we may find that, although the same method of reasoning holds good, the surge will be completely damped out long before $20\frac{1}{2}$ waves are completed and the maximum-interference speed is reached, and that beyond this point the slightly out-of-phase wave-motion is not of sufficient intensity to start vibration of the spring. Under these conditions it can be expected that at low speeds the spring will be wholly free from surge at non-resonant points, but that at high speeds it will never be wholly free from surge, the spring vibrating under the influence of a strong, though slightly out-of-phase, harmonic just passed or just about to be attained.

These ideas as to non-resonant speeds are important, and they are rather well shown by the telemeter oscillograms, which bring out the importance of non-resonant high speeds because, in nearly every case, the residual surge at these speeds is considerably greater than the surge at low resonant-speeds. The effect of the design









Enlarged Details of Oscillograms

To Reproduce the Complete Oscillograms, It Was Necessary To Reduce Them So Much that Details Are Lost, and the Extremes of the Vibrations Are Indicated by White Dots. Sections of Figs. 6 and 7 Are Shown Above, Reproduced the Same Size as the Originals

Fig. 8—Tenth Harmonic, at 1650 R.P.M.

Fig. 9—Twenty-First Harmonic, at 785 R.P.M.

Fig. 10—Twelfth and Twenty-Fourth Harmonic at 1375 R.P.M.

Fig. 11—Sixteenth Harmonic, at 1030 R.P.M.

Fig. 12—Twelfth Harmonic at 1375 R.P.M.

FIG. 13—OSCILLOGRAM OF SPRING NO. 1 AND CAM NO. 2, FROM 2150 TO 1150 R.P.M.

of the spring upon these non-resonant-surge values will be discussed later.

The oscillograms reproduced in Figs. 6 to 20 were taken to show the way in which different springs operate when actuated by cams having different harmonic characteristics. The characteristics of the cams and springs used are summarized in Tables 1 and 2, respectively. Speeds mentioned in the following description are camshaft speeds.

Fig. 6 shows the operation of spring No. 1 and cam No. 1 through a range of speed from 1750 to 750 r.p.m. There are many interesting resonant points on this oscillogram. The worst surge is observed at a speed of 1650 r.p.m., at which point there are 10 free waves of fundamental frequency for the spring per revolution of the camshaft. These 10 waves are maintained by the strong tenth harmonic, which had a greater amplitude on the lift curve than any harmonic of a higher order. It is interesting to note that the 10 free waves shown at this point are not pure waves, but are influenced by the twentieth harmonic, giving rise to a very slight wave between the waves of fundamental frequency. This indicates that the spring is vibrating in its fundamental, with a very feeble first overtone. A full-size section of the oscillogram for this point is shown in Fig. 8.

At a speed of 1570 r.p.m., shown also in Fig. 9, another interesting resonant point can be detected. At this speed the spring vibrates freely, with 21 waves which have double the frequency of the fundamental wave-motion.

The next resonant point occurs at 1500 r.p.m., where the influence of the eleventh harmonic causes the spring to have 11 fundamental waves per camshaft revolution. As in the case of the tenth harmonic, the twenty-second harmonic gives rise to a feeble overtone in the vibration at this speed.

When a speed of 1375 r.p.m. is reached, the spring surges slightly under the combined influences of the twelfth and twenty-fourth harmonics. Both of these harmonics were found to be very feeble, and the resulting wave-shape seems to be a complex wave in which the first

TABLE 1—COMPUTED AMPLITUDES OF HARMONICS OF VALVE-LIFT CURVES

Harmonics No.	Cam No 1 In.	Cam No 2 In.
25	0.0004	0.0001
24	0.0001	0.0001
23	0.0000	0.0001
22	0.0006	0.0007
21	0.0002	0.0003
20	0.0003	0.0001
19	0.0000	0.0003
18	0.0005	0.0007
17	0.0007	0.0006
16	0.0004	0.0001
15	0.0003	0.0009
14	0.0011	0.0013
13	0.0010	0.0010
12	0.0000	0.0011
11	0.0028	0.0031
10	0.0031	0.0026
9	0.0015	0.0002
8	0.0029	0.0045

FIG. 14—OSCILLOGRAM OF SPRING NO. 2 AND CAM NO. 1, FROM 1750 TO 750 R.P.M.

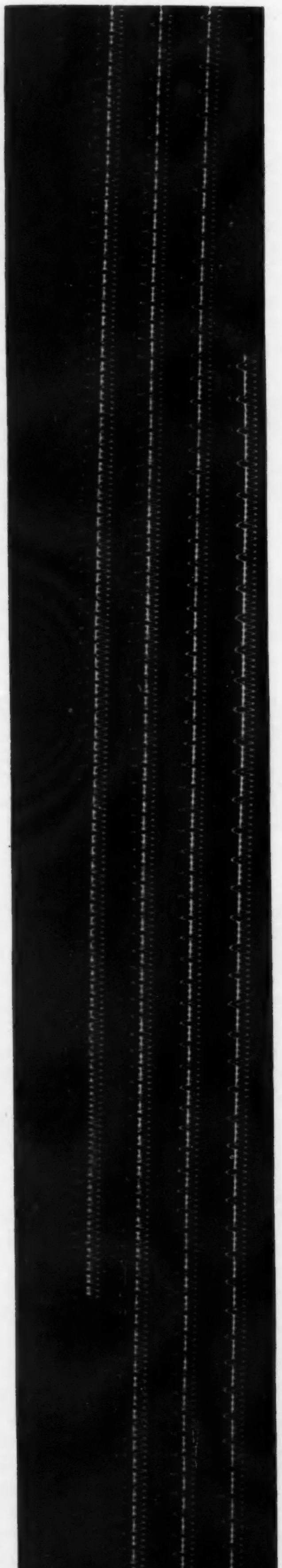


FIG. 15—OSCILLOGRAM OF SPRING NO. 2 AND CAM NO. 2, FROM 1750 TO 750 R.P.M.

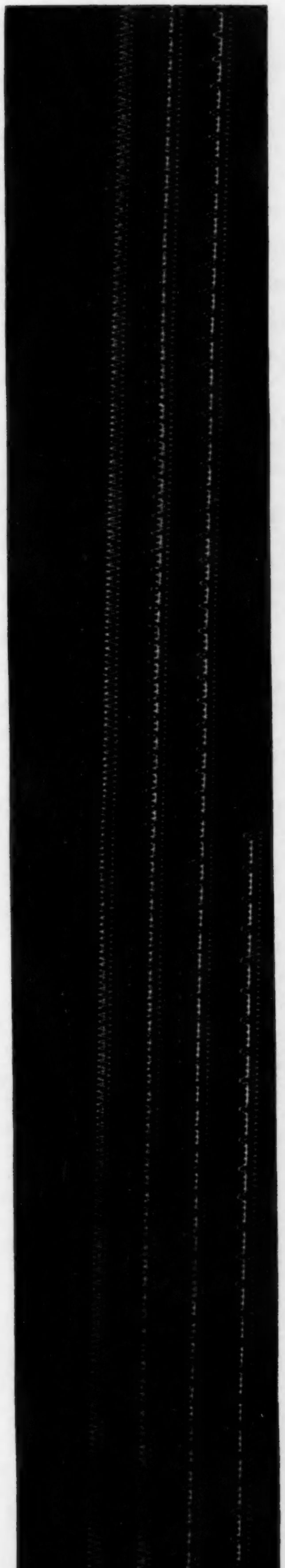


FIG. 16—OSCILLOGRAM OF SPRING NO. 3 AND CAM NO. 1, FROM 1750 TO 750 R.P.M.

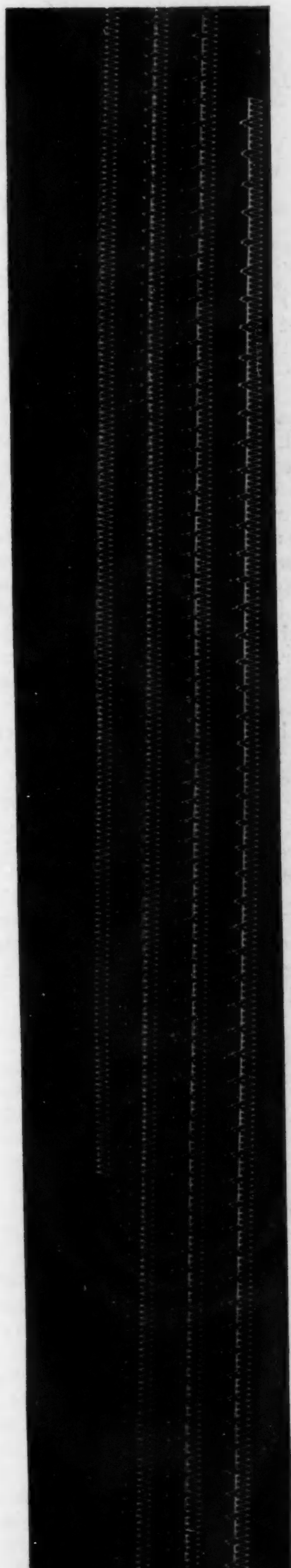


FIG. 17—OSCILLOGRAM OF SPRING NO. 3 AND CAM NO. 2, FROM 1750 TO 750 R.P.M.

TABLE 2—SPRING CHARACTERISTICS

Spring No.	1	2	3	4
Pitch Diameter, in.	0.998	1.000	1.008	0.908
Free Length, in.	2 23/32	2 3/4	3	2 25/32
Total Number of Coils	9 1/2	9 1/2	12 1/4	9
Pitch	Uniform	Variable	Uniform	Variable
Load, valve open, lb.	74.0	77.0	72.0	104.0
Load, valve closed, lb.	46.5	47.0	50.5	68.0
Stress, valve open, lb. per sq. in.	57,800	60,000	56,800	73,700
Stress, valve closed, lb. per sq. in.	36,300	36,700	39,800	48,200
Static Stress-Range, lb. per sq. in.	21,500	23,300	17,000	25,500
Free Frequency, vibrations per min.	16,500	16,500	12,000	21,500

Note.—The ends of all springs are closed and ground square. Gage of wire for all springs, Washburn & Moen No. 9 (0.148 in.).

overtone has almost the same amplitude as the fundamental. It is of interest to note that surge at this point escapes visual or audible detection. This portion of the curve is shown again in Fig. 10.

The resonant points for all the speeds and harmonics can be seen in Fig. 6. It should be noted that the highest speed at which there is no overtone in the wave motion is 1030 r.p.m., at which speed the exciting force seems to be the sixteenth harmonic alone. This indicates that harmonics above the thirtieth are either absent or are very feeble. It should also be noted that nothing on the oscillogram indicates a resonant condition due to the nineteenth harmonic, which was found in the harmonic analysis to be negligible.

In a general way the magnitude of the surge at the resonant points checks well with the calculated values for the amplitudes of the harmonics. This can be verified by comparing Fig. 6 and the detail views with the harmonic values for cam No. 1 in Table 1.

A further point is of interest in connection with Fig. 6. At the peaks of the valve-lift curve at resonant speeds, if the free waves have a crest, or rise above the lift curve, the corresponding calculated harmonic is positive; and if the free waves have a trough, or fall below the lift curve, the corresponding harmonic is negative.

Slight Change with Different Cam

The oscillogram in Fig. 7 shows the operation of spring No. 1 and cam No. 2 through a range of speed from 1750 to 750 r.p.m. Except at certain resonant points, the oscillogram is very much the same as that of Fig. 6. One point of difference between the two is that the twelfth harmonic has a very feeble effect in Figs. 6 and 10, but causes very appreciable surge in Figs. 7 and 12. Also, no twenty-fifth harmonic is noted in Fig. 6, but in Fig. 7 it causes resonance at a speed of 1300 r.p.m., the spring vibrating in its first overtone. The sixteenth harmonic, which causes appreciable surge in Fig. 6, is absent in Fig. 7; and the nineteenth, which is absent in Fig. 6, has an effect in Fig. 7. All these differences are borne out fairly well by the differences in the harmonic values of Table 1.

The oscillogram shown in Fig. 13 was made to record the operation of the same spring and cam at still higher speeds, from 2150 to 1150 r.p.m. The most interesting point on this oscillogram occurs at 1835 r.p.m., at which point there is a slight resonance-peak due to the combined effects of the ninth and eighteenth harmonics. It is to be noted that this peak is bordered by violent surges due to the eighth harmonic on one side and the very bad tenth on the other. Table 1 shows that the eighth and tenth are strong harmonics, while the ninth is very feeble. Another interesting fact to be learned from Fig. 13 is that there is a decided tendency for the higher harmonics to cause the spring to vibrate at double frequency at high speeds.

Variable Pitch Improves the Spring

The oscillograms shown in Figs. 14 and 15 represent the operation of spring No. 2, which is identical with spring No. 1 except that it is wound with a variable pitch. The speed range is from 1750 to 750 r.p.m., and cams Nos. 1 and 2 were used, as indicated in the captions. A fraction of an active coil is closed in the valve-closed position so that spring No. 2 has a slightly higher frequency than spring No. 1. As the valve opens, the effective coils of spring No. 2 decrease until valve-open position is reached, at which point about 2½ active coils are closed up.

This variable-pitch action causes the frequency of the spring to vary continuously during the valve-lift part of the cycle, therefore the spring can never attain a completely resonant condition. However, the spring does vibrate rather badly at times on the base-circle part of the curve, which can be accounted for by the fact that the spring is rather low in frequency and that the lower harmonics tend to excite the spring when the valve is closed and the frequency of the spring does not change.

Figs. 14 and 15 demonstrate that, simply by varying the pitch of the spring as described, bad resonant points can be avoided. However, there are at times slight maximum and minimum points in the surge amplitude, which are determined by the amount of interference present in the wave motion at any time.

Springs Designed To Compress Solid

Figs. 16 and 17 are oscillograms made with spring No. 3, which was so designed that, when the valve is wide open, the spring lacks but 1/64 in. of being compressed solid. Speeds and cams were the same as for Figs. 14 and 15. The results show that a certain damping is obtained by having the spring compress nearly solid once during each revolution of the cam. The top of the lift curve is either almost non-oscillatory or the oscillation is of very high frequency. The spring has a very low frequency when operating on the base-circle part of the curve, however, and it surges badly then under the influence of the lower harmonics.

When observed visually and audibly, these two set-ups appear to be even worse than the oscillograms show. Above a certain speed they seem to surge badly all the time, and they are very noisy because of coil-clash. It is doubtful if the full effects of the coil-clash are transmitted through the apparatus to the photographic film.

A High-Frequency Variable-Pitch Spring

Figs. 18 and 19 show the operation of a well-designed high-frequency variable-pitch spring operating through a speed range from 1750 to 750 r.p.m. with the same two cams that were used for Figs. 16 and 17. The freedom of these two oscillograms from resonant points should be noted. Comparison of these oscillograms with those of Figs. 14 and 15 shows the marked superiority of this spring over a low-frequency variable-pitch spring.

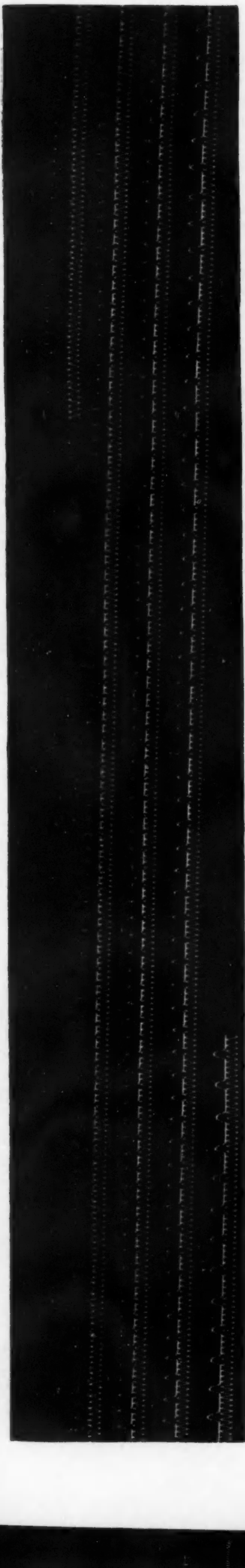


FIG. 18—OSCILLOGRAM OF SPRING NO. 4 AND CAM NO. 1, FROM 1750 TO 750 R.P.M.

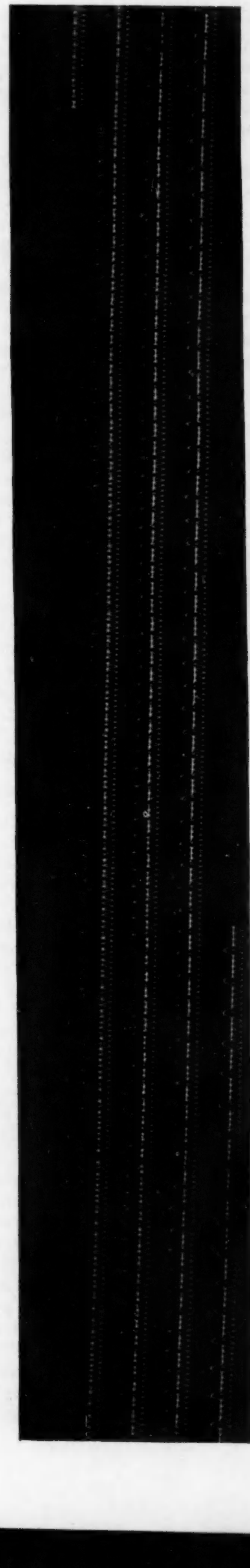


FIG. 19—OSCILLOGRAM OF SPRING NO. 4 AND CAM NO. 2, FROM 1750 TO 750 R.P.M.

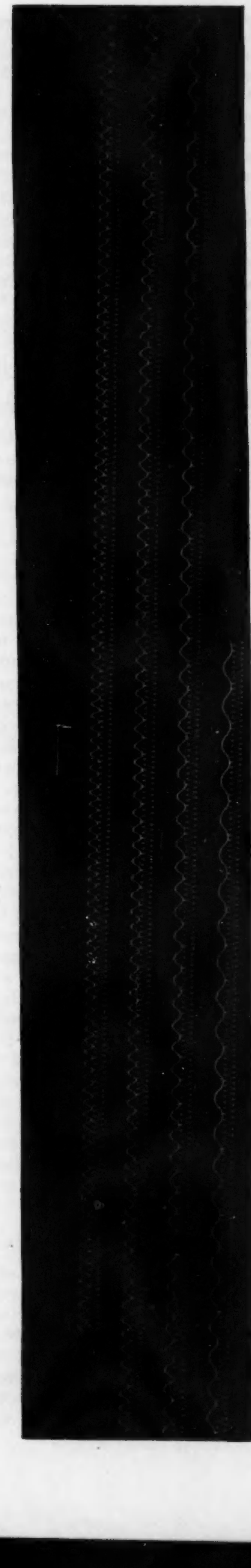


FIG. 20—OSCILLOGRAM OF SPRING NO. 1 AND HARMONIC CAM, FROM 1750 TO 750 R.P.M.

Reference Oscillogram from Harmonic Cam

The oscillogram shown in Fig. 20 was taken to show the operation of spring No. 1 at speeds between 1750 and 750 r.p.m. when actuated by a harmonic cam. The cam was carefully checked and found to impart almost a pure sine-wave motion to the valve. Inspection of this oscillogram shows no resonant points; however, some very feeble waves are present in the lift curve. It is hard to account for the presence of the waves, as their frequency of about 700 cycles per second is not high enough to be caused by the C-spring or the oscillograph elements. It is probable that their source is in some roughness or chatter-marks on the cam or in the valve train, or is in a slightly loose fit of the push-rod or valve-stem. In any event the amplitude of these vibrations is so low that they have no effect on the results. The prime feature of Fig. 20 is its freedom from resonance points.

Dynamic Stresses

It is common practice to calculate the stresses present in valve-spring operation by the conventional formula for stress, which can be expressed

$$S = 8PD/\pi d^3 \tag{2}$$

where S is the fiber stress, in pounds per square inch; P is the load, in pounds; D the pitch diameter of the spring, in inches; and d is the wire diameter, in inches.

Such a formula can be used to good advantage in computing the stresses present in the spring and in determining the stress range through which the spring operates, provided the motion of the spring is non-oscillatory with respect to its free frequency. In other words, the use of this formula will give results when, and only when, a load of P_1 is maintained continuously while the valve is closed and a load of P_2 is attained, exactly and always, when the valve is wide open.

However, in dynamic operation, the oscillatory nature of the vibration of the spring causes the load to fluctuate greatly and with extreme rapidity. For this reason, the conventional stress-formula does not give an indication of the conditions under which the spring operates, except at very low engine-speeds.

In a general way, the values of the actual stresses and stress-ranges vary with the magnitude of the surge, as indicated in the telemeter oscillograms. Since these actual stresses and stress-ranges are factors which are varying continuously whenever the motion of the spring is influenced by its own free frequency, it is impossible to assign definite concrete values to the stress conditions. However, to make clear the high orders of the stresses encountered and the extreme values for the stress ranges under surge conditions, it is well to present some figures which are believed to be of sufficient accuracy to give a picture of the true conditions. For this purpose attention is called to Fig. 8, which shows a spring to be vibrating badly at a speed of 1650 r.p.m., excited by a strong tenth harmonic.

Surge Stresses Evaluated

If particular attention is paid to the lift curve nearest resonance at 1650 r.p.m., a peak swing can be noted very close to the maximum-lift position. The stress at the point would be approximately 60,000 lb. per sq. in. if there were no surge. However, the peak swing of the wave motion produces an additional stress at this point, so that the actual stress at the crest is probably about 146,000 lb. per sq. in. One half-wave later, a trough in the wave motion occurs. At this minimum point, the actual stress is probably 49,000, instead of about 60,000, lb. per sq. in. The true stress-range is therefore 97,000 lb. per sq. in., and it must be noted that this range has been traversed during a half-cycle of the free wave-motion of the spring, or at a rate of 33,000 cycles per minute.

That the stress conditions vary from wave to wave can be seen upon further inspection of Fig. 8. It can be noted that the minimum point of the wave motion for the same lift-curve occurs just before the next lift. Here it is apparent that the crest of the wave motion causes a large addition to the valve-closed stress. The normal valve-closed stress is 36,300 lb. per sq. in., but the stress at the crest of the wave seems to be about 79,300 lb. per sq. in. A half-cycle later, at the trough of the wave, the stress would be zero; hence, the stress range for this half-cycle is 79,300 lb. per sq. in.

At another point, intermediate between the two described above but on the base-circle part of the valve-lift curve where the calculated stress has a constant value of 36,300 lb. per sq. in., inspection discloses the stress at the crest of the wave to be 82,800 lb. per sq. in., while the stress at the trough of the wave is 43,300 lb. per sq. in. less than the normal valve-closed stress. This seems to cause a stress reversal of 7000 lb. per sq. in. and a stress range of 89,800 lb. per sq. in for the half-cycle.

Conditions of zero stress and reversed stress seem to indicate that the spring is in a free position in the first case and is acting as an extension spring in the second case, which is impossible under the conditions. What really is indicated is that, because of the wave motion of the spring, its coils successively assume positions corresponding to that of all the coils when the spring is free or when it is acting as an extension spring.

Spring Frequency Determines Stress Cycle

From the foregoing it can be established definitely that, under highly oscillatory motion such as is encountered at resonant speeds, the spring operates under very severe stress-conditions. At high speeds the stress conditions are very bad, even without resonance. As a rule, it is only at low engine-speeds that the spring can be said to passing through the stress range calculated by the stress formula and that the rate of the stress cycle can be said to be the camshaft speed. At the higher engine-speeds, if the motion of the spring is oscillatory, the stress ranges always will be much higher than the calculated range and the stress-cycle rate will be double the spring frequency—many times the camshaft speed.

In the design of valve-springs it has been found that high-frequency springs are preferable to low-frequency springs. The prime reason for this is that, for the same engine-speeds, the resonant points for the former are due to the higher harmonics. These generally have considerably smaller amplitudes than the lower harmonics, which cause the resonant points in the same camshaft-speed range for the low-frequency springs. The lower harmonic amplitudes cause the surge amplitude to be less for the high-frequency spring, and the freedom from surge seems to increase the fatigue life of the high-frequency spring.

Invariably, increasing the frequency of a valve-spring necessitates making it stiffer, which in turn gives rise to an increase in the stress range as calculated by the usual formula. In reality the actual stress conditions

in the spring that is relatively free from resonant points approach the calculated values more nearly; whereas the conventional stress calculations give absolutely no clue to the true stress conditions in the surging spring. A spring breaks because of the stresses set up in it; no spring breaks when it has a lower actual stress than a similar spring which stands up in service.

CONCLUSIONS

Through the investigations thus far conducted by means of the electric telemeter, we are able to form several conclusions as to the cause of surge, the effect of surge on the behavior of the springs, and the influence of surge on the design of the springs.

Where the cause of surge is concerned, the telemeter has proved to be a valuable instrument, as it furnishes a means for checking the theory that surge is a function of the amplitude of the harmonics of the complete valve-lift curve. This is important because it enables us to work toward the elimination of surge through cam design as well as spring design.

The telemeter enables us to demonstrate that, where surge is encountered, the stress conditions existing in the spring are very severe. In a spring which has resonant points, the calculated stress conditions are realized only at low engine-speeds. At high speeds, the stresses are much greater than the calculated values, and the rate of the stress cycle is many times greater than at low engine-speeds.

The telemeter enables us to draw the following conclusions in regard to the design of valve-springs:

(1) Low-frequency springs are to be avoided because, at engine speeds within the driving range, the springs tend to come into resonance when excited by the lower order of harmonics of the complete valve-lift curve; and the lower harmonics have very appreciable amplitudes, as a rule.

(2) High-frequency springs are to be desired because, within the same driving range, the resonance points are due to the influence of the higher harmonics, which usually have much less amplitude than the lower harmonics.

(3) Springs having a continuously variable pitch are valuable in minimizing the effects of surge. It is important that a few of the active coils should close up solid when the valve is open. The effect of the change in the number of active coils is to alter the frequency of the spring continuously throughout the lift of the valve. Thus, resonant conditions are prevented by interference in the wave motion, although the surge amplitude at high speeds may have certain points of minima and maxima.

(4) High-frequency variable-pitch springs are preferable to low-frequency variable-pitch springs.

(5) As a rule, if more than one to three coils of a variable-pitch spring are closed as the valve lifts, the total number of active coils must be rather large. This will cause the spring to have a low frequency when it is on the base-line portion of the valve-lift curve. The lower harmonics will cause the spring to vibrate badly during this portion of its cycle, even though severe resonant points are eliminated.

In conclusion, the authors wish to express their appreciation to J. L. Whiteman[7] and J. L. Sjolander[7] for their assistance throughout the investigation.

[7] Cleveland Wire Spring Co., Cleveland.

THE DISCUSSION

E. W. STEWART[8]:—The general conclusions drawn from the oscillograms shown in this paper are very instructive, and much information as to the relations existing between harmonics and spring frequencies, as affecting surge, can be obtained from a study of the wave pictures.

The authors say at one point: "A spring breaks because of the stresses set up in it; no spring breaks when it has a lower actual stress than a similar spring which stands up in service." If all wire were perfect as to physical characteristics, microstructure, condition of surface, and hardness, such a conclusion would perhaps be safe. To be sure, when the wire is not perfect, breakage results from localized stresses set up at certain points of weakness under fatigue conditions, such as scratches, nicks from tools, segregation pockets, and numerous other things, and I am of the opinion that imperfect materials are responsible for more breakage than can be charged to surge.

We must design valve-springs that will stand up when made of obtainable commercial materials. To do so we are forced to compromises. Spring No. 4, as described in this paper, for instance, is stressed from 48,200 to 73,700 lb. per sq. in., and presents a very good condition as to frequency and damping of surge from harmonics, but it is so highly stressed at the valve-open position and the stress range is so great that only wire of the best possible quality would be satisfactory.

WIRE FOR SPRINGS NOT UNIFORM

We who turn out valve-springs by the ton do all we can to get materials as perfect as possible, but I know that mill practice in the production of wire in great quantity has not reached a point where we can be assured of the quality of every coil of wire, and I want to go on record as cautioning every engineer who is interested in these problems against going too far in designing high-frequency high-stress springs. You cannot get a carload of wire all of which will stand up in springs of ideal design as to frequencies and surge, and the breakage of such springs because of mechanical defects in material will be very likely to bring much more grief than the possibly greater tendency to a slight surge at certain speeds in springs not so highly stressed.

H. H. CLARK:—In the statement that no spring breaks at a lower stress than a similar spring will sustain, we merely meant to call attention to the fact that stress was the prime cause of failure, not to start any discussion of heat-treatment, chemical content or physical structure.

[8] M.S.A.E.—Sales manager, William D. Gibson Co., Chicago.

Spring No. 4 is being used by a car manufacturer now, and it has given good results.

Adaptability of the Electric Telemeter

S. Timoshenko[9]:—The authors are to be congratulated for their very interesting paper. The application of the electric telemeter gives us the possibility of direct measurements of the force acting in the spring during vibrations, on the basis of which the stresses can be calculated. Attention should be paid to the frequency of natural vibrations of the instrument itself. Recording instruments built on mechanical principles usually are unsatisfactory for recording high-frequency vibrations, because the frequency of natural vibration of the instrument is low and the vibrations of the instrument itself may affect the record considerably. For that reason electric instruments usually are applied for recording high-frequency vibrations. The authors observed this, and they proportioned the C-spring to have a natural frequency of 1000 per sec., much higher than the frequencies of vibrations they had to measure. The frequency of the natural vibrations of the oscillograph also has been discussed by the authors, but there are no data regarding the natural frequency of the telemeter itself. Our experience has shown that this frequency is not very high; for instance, the telemeter designed by O. S. Peters has a frequency of about 500 per sec.

Another type of telemeter, used by Dr. Siemann in Germany[10], has a frequency of 200 per sec. A much higher frequency has been found for the new type of telemeter developed by Dr. R. Bernhard[11] and used by him in studying bridge vibrations. Assuming that the frequency of natural vibrations of this instrument is about 500 per sec., it must be concluded that these vibrations would affect some records, especially those of the higher harmonics. Perhaps the presence of waves in the oscillogram made with the sine-curve cam can be attributed to these vibrations of the instrument itself.

Another point of importance when experimenting with a telemeter is that the electrical resistance of the instrument changes with the time; the telemeter should be under current not less than 5 min. before taking records, to obtain satisfactory results.

Conditions can be improved by using high-frequency variable-pitch springs; but vibrations, although diminished, always will exist. This suggests making investigations of the internal friction of spring steel and fatigue tests of spring steel.

Study Internal Friction and Fatigue

It is a well-known fact, as stated by F. M. Lewis[12], that in damping resonance vibrations the internal friction of the material may be of practical importance, and the damping properties of various kinds of metals vary much. We know that the damping due to internal friction is of practical importance in the vibration of a big shaft. Investigation of the damping properties of various spring steels may yield some interesting and practical results.

The investigation of fatigue of metals has been developed considerably during the last ten years, but only a little information is available for use in spring design. Most tests have been made with complete reversal of stress, while in springs the stress usually fluctuates between certain limits without change of sign. The existing results give us the endurance limit of steel in tension and compression; but in springs we have shearing stresses due to twisting, and there is no constant relation between the endurance limits in tension and in shear.

Another point of importance is that quenched-steel spring-material, on account of its hardness, as brought out by D. J. McAdam[13], is very susceptible to the effect of surface defects.

Mr. Clark:—The telemeter gage that we used has a frequency of approximately 500 cycles per sec. We think that the vibrations mentioned in the case of the harmonic cam cannot be attributed to the gage frequency. In a paper on Recent Developments and Applications of The Electric Telemeter[14], O. S. Peters made a comparison of an oscillogram of direct mechanical displacement with an oscillogram made by means of the telemeter. Although the harmonics of the forced vibrations reached a value as high as 570 cycles per sec., no appreciable difference was noted in the two records The gage used in these experiments had a frequency of only 250 cycles per sec.

If the tongue and thrust arm of the telemeter gage were free to vibrate as a mass, the frequency of the gage might affect the higher harmonics of the frequencies being investigated. In our case, as in the case mentioned in the preceding paragraph, the thrust arm and tongue of the gage act as a load on the C-spring. This may slow up the C-spring somewhat; but the vibration of the gage does not enter, as the gage is forced to vibrate at the frequencies of the C-spring with its loaded arm.

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[9] Professor of engineering mechanics, University of Michigan, Ann Arbor, Mich.

[10] See *Zeitschrift des Vereins deutscher Ingenieure*, April 17, 1926, p. 539, and May 8, 1926, p. 635.

[11] See *Der Stahlbau* (supplement of *Die Bautechnik*) Sept. 21, 1928, p. 145.

[12] See *Transactions of the Society of Naval Architects and Marine Engineers*, vol. 33, 1928, p. 109.

[13] See paper presented at the annual meeting of the American Society of Mechanical Engineers, December, 1928.

[14] See *Proceedings of the American Society for Testing Materials*, vol. 27, 1927, part 2, p. 522.

Idiosyncrasies of Valve Mechanisms

Discussion of Annual Meeting Paper[1] by Ferdinand Jehle and W. R. Spiller

SOME of the discussers introduce other formulas than those given in the paper for spring vibration and discuss the application of the formula

$$C = (K/\triangle) \times (d^3/DN) \times a_n \qquad (2)$$

in which C is the maximum amplitude of spring vibration; K is a constant of proportionality, dependent also on the spring material; d is the diameter of the wire; D is the mean diameter of the coil; N is the number of active coils; a_n is the largest valve-lift harmonic that can come into resonance with the spring; and $\triangle$ is a damping factor.

Experiences also are quoted by several discussers, much of it confirming the findings of the authors. However, one speaker is opposed to variable-pitch springs because of alleged noises and wear resulting from coil clash.

Materials, heat-treatment and hardness tests for springs are discussed by a member who favors the use of carbon steel because of more uniform results than have been secured with alloy steels of apparently higher properties.

Some of the discussion has to do with the Donkin and Clark paper beginning on p. 315 in this issue of the S.A.E. JOURNAL.

E. W. STEWART[2]:—The ingenious mechanism described in this paper for determining valve-spring performance optically is a distinctly valuable contribution to the problem, and the harmonic analysis developed has great possibilities of practical application. My experience confirms the statement that valve performance depends upon the spring characteristics in their relation to the cam characteristics. In working with designers of new engines, we have found a number of times that a badly acting valve-train has been remedied by changing the cam contour with no change in the spring. The valve-lift curve and the spring should be very carefully worked out together, as each depends upon and affects the other.

The authors have used the formula given by Andrew Swan for the calculation of frequency, and it may be of interest to compare this with Ricardo's formula for the spring frequency, which he gives as $531\sqrt{(R/W)}$, in which R is the rate, or scale per inch, of the spring in pounds, and W is the actual weight in pounds of the active portion of the spring. This, reduced to the same terms as used in Swan's formula, becomes

$$F = 224\, d\sqrt{g}/D^2N$$

The actual frequency determined for the spring tested would indicate that the constant should be 242, between the values given in the two formulas.

During the few days since this paper was received I have checked as many springs against the harmonic curve submitted as time would permit, with some interesting results. I had some records of a spring that we tried out on a high-speed job not long ago, which gave a very fair performance up to a camshaft speed of about 1350 r.p.m., went through a severe series of surge antics up to 1800 r.p.m., then settled down and ran smoothly. This spring was of uniform pitch, and we changed it to close out part of the coils during the valve lift by varying the pitch, which made it behave. The frequency by the revised formula, using a constant of 242, is 16,400 for the free spring, indicating that between 1350 and 1800 r.p.m. it was passing through the high-amplitude tenth and eleventh harmonics shown in Fig. 13 of the authors' paper, and at 1800 r.p.m. it settled into the relatively flat ninth harmonic. By graduating the pitch we damped out the tenth and eleventh harmonics, but we did not know it then.

I can readily see that this chart of harmonic amplitudes can be made of great value in the design of valve-springs, and feel that the subject has been made much more clear by the work of Mr. Jehle and Mr. Spiller.

There appears to me to be a little obscurity in the application of equation (2) in the paper, expressing the amplitude of vibration. In the calculation of frequency, the highest is obtained when the wire size is as large as possible, with the diameter of coils and the number of coils as small as possible. In the equation stated, the least amplitude is obtained when these conditions are exactly reversed. The authors say: "The smallest wire-size consistent with the stress, load and frequency requirements should be used, to minimize vibration. The number of coils and their diameter should be made as large as possible." Various combinations of wire-size and diameter of coil which would reasonably suit as to stress, load and frequency would perhaps be possible; and as I understand this paragraph it is intended to convey the thought that these three requirements must be met, but that the spring of least wire-size which will meet them would also have the least amplitude. Will Mr. Jehle check me on this?

WIRE QUALITY IS LIMITING FACTOR

The one danger in the application of these developments is that of working up to stresses which are dangerous with available materials. When we consider surge in valve-springs from the standpoint of engine performance, volumetric efficiency as affected by valves following cam contour, and overlapping of inlet and exhaust, we would like to do away with surge at all speeds. From the standpoint of possible breakage, however, it probably is true that our ability to design ideal valve-springs has already surpassed the wire makers' ability

[1] Published in the S.A.E. JOURNAL for February, 1929, p. 133. Mr. Jehle is research engineer, and Mr. Spiller laboratory engineer, of the White Motor Co., Cleveland. Both are members of the Society. An abstract of the discussion is given herewith, but the abstract of the paper published last month is not reprinted.

[2] M.S.A.E.—Sales manager, William D. Gibson Co., Chicago.

to produce materials which will stand up consistently. We must do the best we can as to surge, by making every possible use of such information as this paper contributes, but still keep top stresses and stress ranges within figures that commercially obtainable wire will meet, until we can get the mills to keep pace with us by providing more perfectly fabricated materials.

A great deal of constructive work along that line is in progress, but there are many limitations to the quantity production of perfect—or anywhere nearly perfect—wire, at a price the traffic will bear. Die scratches, hair-line seams, minute surface-pits, surface decarburization, slight inclusions of dirt, manganese-sulphide pockets, and other defects from a fatigue standpoint are still with us more or less.

FERDINAND JEHLE:—Mr. Stewart points out the discrepancy between the measured and calculated frequencies of a spring in our paper and suggests correction by changing the constant in equation (1) to 242. This discrepancy, however, is due to the lower frequency because of the shutter wire that was attached to the spring, as is pointed out in the paper.

In his experiments on the relation of certain dangerous harmonics of the camshaft to spring vibration, Mr. Stewart does not make clear that the harmonics are those of the particular shaft he tested. It is hoped that the readers will understand that the harmonics given in Fig. 13 and Table (1) of the paper apply only to the particular cam contours studied. Each cam contour requires a separate analysis.

Mr. Stewart has the correct understanding of equation (2); that is, the spring should be made of the smallest diameter wire, and with the largest coil diameter and the greatest number of active coils, that will meet the stress and load requirements and still put the frequency high enough so that the first 10 or 11 harmonics will be above the highest operating speed.

MATHEMATICAL ANALYSIS OF VIBRATION

S. TIMOSHENKO[3]:—This paper contains a description of various methods of experimental investigation of valve motion and valve-spring vibrations, and also a theoretical analysis resulting in an equation (2) for determining the most favorable proportions, considering vibration, of valve-springs. This equation is derived on the basis of a simplified theory, and we do not feel that there is given in the paper a satisfactory proof that the equation represents the actual conditions with sufficient accuracy. At the same time, the equation is in disagreement with practice as regards valve-springs; namely, in using this equation we should diminish the diameter of the spring wire and at the same time increase the diameter and number of coils. This means that the equation brings us to a diminishing of the stiffness of the spring and the frequency of its natural vibrations, while there are indications that better service can be obtained by increasing the frequency of natural vibrations of springs.

In deriving the equation mentioned, the authors use the theory of vibrations of a system with one degree of freedom. This theory cannot yield a satisfactory result in this case when the mass of the spring alone should be taken into consideration, and the propagation of waves along the spring must be investigated. The longitudinal vibrations of the spring will be represented by the same equation as the longitudinal vibrations of a prismatical bar. Taking the origin of the coordinates at one of the ends of the spring and the X axis in the direction of the axis of the spring, the equation for determining displacements u along the X axis will be, as given in my book[4]

$$\frac{\partial^2 u}{\partial t^2} - v^2 \frac{\partial^2 u}{\partial x^2} = 0 \tag{3}$$

in which t is the time and v is the velocity of propagation of longitudinal waves in the spring.

The velocity, v, is determined by the equation

$$v = \frac{ld}{4\pi NR}\sqrt{\frac{Gg}{2\gamma}} \tag{4}$$

in which l is the length of the spring, d is the diameter of the wire, N is the number of coils, R is the mean radius of the coils, G is the modulus of steel in shear, g is acceleration due to gravity, and γ is weight per unit volume of the material.

The period of time, $T = 2l/v$, necessary for the wave to travel the distance $2l$, gives the period of the fundamental type of vibration of the spring with fastened ends.

Assuming that the end, $x = l$, is submitted to the vibratory motion given by equation

$$u_{x=l} = \delta \sin mt \tag{5}$$

forced vibrations of the type

$$u = \frac{\delta}{\sin ml/v} \sin \frac{mx}{v} \sin mt \tag{6}$$

will be produced, m being 2π times the frequency of vibration.

From this expression it is seen that when $ml/v = n\pi$, n being an integer number, the conditions of resonance exist. At this condition the period $2\pi/m$ of an oscillation of the end is equal to $2l/nv$, that is, to the period of one of the natural vibrations of the spring with fastened ends. It is seen also that the force necessary to produce oscillatory motion (5), which is proportioned to $\partial u/\partial x$ is not in proportion to the acceleration of the end, as is assumed in the paper.

MR. JEHLE:—We welcome Professor Timoshenko's mathematical criticism, but we can find in it no constructive suggestion for reducing spring vibrations by the correct selection of spring dimensions. If this mathematical analysis proves that the spring having the highest frequency is the best performing spring, then it does not agree with experiments.

There seems to be some misunderstanding of equation (2) in the paper. Springs made according to equation (2) are not necessarily of very low frequency. The minimum frequency of the spring is definitely limited in this equation and is set to such a magnitude that the dangerous harmonics are definitely outside of the operating range. Raising the frequency above this minimum never resulted in a better spring and frequently results in one having greater vibrations. The vibration of springs of the same frequency can be varied by changing values in the second portion of equation (2), and thus far the spring that has been the best performer is the one whose dimensions are such as to make C in the equation the minimum.

GEORGE P. NELSON[5]:—One cause of spring vibration not covered in either of the papers presented is the torsional vibration of the camshaft, caused by its lightness

[3] Professor of engineering mechanics, University of Michigan, Ann Arbor, Mich.

[4] Vibration Problems in Engineering, D. Van Nostrand Co., Inc., 1928.

[5] Chief engineer, Plant No. 2, L. A. Young Spring & Wire Corp., Detroit.

and length and by the intermittent load and backlash in the drive.

Noise is among the many factors to be considered. All variable-pitch springs are more or less noisy, as their damping quality is caused by coil clash. Low-frequency variable-pitch springs are noisier than high-frequency variable-pitch springs because of the higher amplitude of the lower harmonics. Another difficulty is that wear will occur in the end coils because of the coil clash, resulting in premature failure at this point because of the reduced cross-section of the wire. Low-frequency springs will wear more rapidly because of the greater amount of coil clash.

There is a limit to the application of all the conclusions; therefore, the spring designer has been accustomed to make compromises of the following desired factors:

High frequency, which is obtained by high rate or load per unit of deflection and low mass of active wire, and is limited by excessive load and wear on the valve mechanism, due to high stresses.

Damping, which is obtained by variable pitch or friction from external sources, and is limited by the noise and wear that it causes.

MR. JEHLE:—From our experiments we cannot attach the same importance to the torsional vibration of the camshaft as a cause for spring surge that Mr. Nelson does. The experimental camshafts used were very husky; the length from drive end to cam was only 5 in., and the distance from center to center of bearings was 4 in. Valve-spring surge occurred at the same speeds and the same amplitudes whether the springs were run on the test machine with this shaft or in the engine with a full-length camshaft of the same diameter.

To produce coil clash it is necessary that the spring surge. A well designed valve-spring does not surge and therefore cannot produce coil clash, regardless of whether the spring is of variable pitch or constant pitch. Therefore, we do not agree with Mr. Nelson that coil clash is inherent in variable-pitch springs. In our experience with valve-springs we have never seen one that failed because of reduced cross-sectional area due to wear.

METALLURGICAL ASPECTS OF VALVE-SPRINGS

W. P. WOOD[6]:—Valve-spring design has always been concerned with the quality and properties of the steel from which the springs were to be made. This is increasingly true with the present demand for speed and pick-up in motor-cars. The day when valve-springs could be coiled from fence-wire is most decidedly past. Great responsibilities are placed upon the steel manufacturer and the metallurgical department under whose supervision the springs are fabricated. Good valve-springs in the modern automobile with the control methods of a decade ago would at best be a most fortuitous circumstance.

Since all will readily admit that a valve-spring designed on the soundest mechanical principles will fail if made from inferior or grossly mishandled good material, it may not be amiss to consider a few of the factors which constitute the link between satisfactory material and proper design.

Three general types of steel are available for valve-springs: (*a*) hard-drawn wire, (*b*) wire heat-treated before coiling, and (*c*) wire coiled soft and heat-treated after coiling. Further, either carbon or alloy steel can be used for the last two.

It would be futile to attempt a complete discussion of the factors entering into this choice of material; in most cases the final decision is arrived at only after exhaustive and in many cases contradictory tests. This choice of material is largely influenced, as it should be, by the stresses involved and by fatigue resistance. Certain types of alloy steels certainly exhibit greater resistance to fatigue than do carbon steels, yet how many have had the experience of deciding upon an expensive alloy-steel and then, when production was started, suddenly finding themselves in an epidemic of breakage, the cause of which is found to be defective stock?

This brings up the question of uniformity in steel. Is the steel manufacturer able to guarantee that every heat of the special steel will be of the same superior quality as was found in the heat from which the experimental springs were made? To be brutally specific in regard to a certain steel, in several years' experience I never have found a case in which chromium-vanadium S.A.E. steel 6150 would show the same uniformity over a given production-period as is usually found in a good carbon-steel. The fundamentally superior properties of 6150 steel are readily admitted, and this observation is submitted merely as a cold and troublesome fact.

HEAT-TREATING AND HARDNESS TESTS

I have wondered often whether a carbon-steel valve-spring, carefully heat-treated after coiling, would not in many cases render just as good month-to-month service as some of its brilliant but more erratic cousins, because of the better chance of uniform stock.

The mention of heat-treating after coiling brings up several interesting points. It is only during the last five years that the use of heat-treated springs has been noted. All things considered, remarkable results have been and are being secured by the use of wire heat-treated before coiling. There is a widespread belief, however, and it is felt to be a correct belief, that the maximum properties are secured by heat-treatment of a soft-wire spring after coiling.

If springs are heat-treated after coiling, some method of control must be adopted to be sure that the wire has acquired the elastic limit and tensile strength that are known to exist in springs made from heat-treated wire. One of the best available methods is by the use of hardness determinations; and of the various instruments used in determining hardness, the Rockwell offers many advantages for springs. Since valve-springs are made from round wire, considerable difficulty is experienced if it is attempted to make the test without removing some of the curvature with a file or by other means. Special jigs are sometimes used by means of which a solid round piece of metal is thrust through the spring to support it. Unless this anvil possesses exactly the same curvature as the spring, however, erroneous results will be obtained. It is necessary also to support the anvil at both ends, since a cantilever support usually will allow enough bending to render the results doubtful.

While it is somewhat cumbersome, I have found the following method valuable, since it eliminates all possibility of error due to insecure support. Three or four coils are cut from the spring and the ends are bent laterally until the coils are in the shape of rings. These

[6] Cook Spring Co., Ann Arbor, Mich.

rings are then placed on a magnetic chuck, and a small amount of the curvature is ground off at each side. It now is possible to make a Rockwell determination, using one of the anvils supplied with the machine. If springs are being heat-treated after coiling, it is absolutely essential to test a certain small percentage of them in some such manner.

For carbon-steel springs, it has been our experience that a hardness of 42 on the Rockwell C scale represents about the average in the satisfactory range. With a hardness of C-36, many springs will show a tendency to set, and they are liable to breakage if the hardness runs much above 47. This figure may be raised slightly for alloy steels of some types, but as a rule the hardness range which lies just above the point where setting is encountered represents the best condition for satisfactory performance. It is entirely possible to hold the hardness within 3 or 4 points on the Rockwell C scale.

What has just been said regarding hardness limits applies also to valve-springs made from so-called tempered wire, but it is not so easy to bring the springs finally within as small a range of hardness numbers.

Spring Failures Result from Fatigue

Every metallurgist has been asked at some time to furnish an explanation for a given valve-spring failure. He of course tries his best to find a defect such as a seam, a surface lap or dirt in the steel. In some cases the failure can be traced to some such defect, but in about 90 cases out of 100 no defect is discoverable. How, then, shall we account for the failure? If the surfaces of such fractures are carefully examined they will many times show the appearance of fatigue failures. When frequent failures of this nature occur, the steel should not be summarily condemned without a thorough review of the design of the spring, to see whether it is overstressed at the point of failure. Particularly is this true if there is any probability of surge occurring in the spring. It should always be kept in mind that steel has its limitations; it can do so much work and no more.

In making valve-spring calculations it is frequently necessary to use the torsional modulus of steel. While this is fundamentally a constant, there has been considerable difference of opinion as to just what figure to use. The values have varied from 10,000,000 to nearly 13,000,000. In a paper presented before this Society three or four years ago, E. W. Stewart[7], of the Gibson Spring Co., reported the results of many determinations which he had made of the torsional modulus of steel. He concluded that the correct figure is 11,500,000. About 18 months ago we set up a special apparatus for determining the modulus and ran several hundred tests on different varieties of steel. The results of this work were presented in a paper read at the October, 1928, convention of the American Society for Steel Treating. The grand average of all our tests on steel was almost identically the same figure as Mr. Stewart obtained. I believe that now we are justified in ceasing to wonder just what figure should be used and all agreeing on this value of 11,500,000 for carbon steel. It would at least make for a little more uniformity in design and eliminate small but frequently noticed differences in results figured by different engineers.

Uniformity and Smooth Finish Needed

W. T. Donkin[8]:—Both of the papers presented deal solely with the design of springs and their relation to valve mechanisms and operating conditions rather than with material. As the question of material covers such a large field and no short discussion would do it justice, I suggest that it be given future consideration by the Society.

It seems that Mr. Wood's remarks in regard to carbon and alloy steel are misleading, because of the lack of exact definitions of the terms. The chance of disaster certainly is just as great, if not greater, with the ordinary run of carbon-steel wire now on the market as with alloy steel. Moreover, there has been a lack of the spirit to progress among the carbon-steel-wire manufacturers, as a questionnaire on surface requirements sent to them bears witness. We had to appeal to an alloy-steel-wire maker to give us carbon-steel wire having the surface specifications desired.

Uniformity, of course, is paramount in springs. Mr. Wood's statement, that he has never found a case in which chromium-vanadium S.A.E. steel 6150 would show the same uniformity over a given production period as a good carbon-steel, conflicts with data collected over a five-year period and the experience of a number of engine builders. Of course, we do not know what kind of chromium-vanadium S.A.E. steel 6150 Mr. Wood refers to, but we do know that electric-furnace chromium-vanadium steel of the correct physical properties and heat-treatment has given the best results of any material used during the last five years. This last statement should not be construed to mean that there has been no trouble with this material, for there has been, which indicates that there is room for improvement.

It is admitted that the chromium-vanadium and carbon-steel wires compared were not of the same quality, for the simple reason that no carbon-steel wire could be procured which was manufactured with the same care as the higher-priced alloy. During the last year, several American and some foreign wire manufacturers have interested themselves in producing a carbon material that has given excellent results both as to fatigue and uniformity. This development may mean a general improvement of quality all along the line of carbon and alloy steels.

Contrary to the experience of Mr. Wood, we have some very complete data on the effect of surface imperfections on the fatigue life of springs. This data includes both test and service records.

Spring Vibrations Charted

H. A. Huebotter[9]:—Fig. 1 herewith shows the elastic vibrations in a helical valve-spring induced by the motion of the valve at three different camshaft-speeds, and following are the data and method used in their computation.

The valve, whose lift is indicated by the curve L, remains open for 240 deg. of crankshaft rotation. The valve-spring has 11 free coils of No. 8 W & M-gage ($d = 0.162$-in.) steel wire, whose mean diameter D, is 1.44 in. The length, l, of the wire in the free coils is therefore 50 in.

The elastic stress incidental to the opening of the valve is transmitted along the wire at a velocity of

$$v = d/D \sqrt{(G/2m)} \qquad (7)$$

where d and D are given in the spring specifications, G

[7] See The Journal, August, 1925, p. 195.
[8] A.S.A.E.—Engineer, Cleveland Wire Spring Co., Cleveland.
[9] M.S.A.E.—Chief engineer, Butler Mfg. Co., Indianapolis.

is the modulus of elasticity in shear, and m is the unit mass of the material. For the spring in this problem, $i = 10{,}000$ in. per sec., and the stress travels the free length of the spring and returns in 0.01 sec.

It can be shown mathematically that the increase in spring stress due to the opening of the valve is proportional to the slope of the valve-lift curve L. This slope is defined by the curve A which, in common with the lift curve, is plotted on a base whose length represents the distance an elastic wave will travel through the wire while the valve is open.

After the initial stress-wave, whose characteristics are represented by the curve A, traverses the double length of the spring, it is reflected with doubled amplitude and the effect of the reflected wave is superimposed

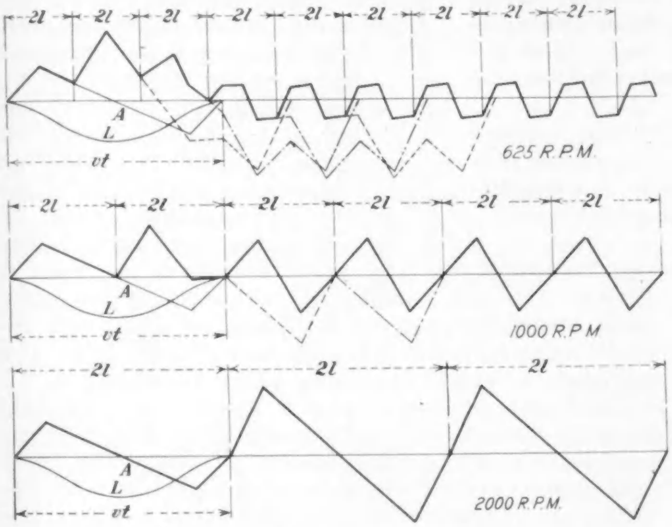


FIG. 1—ANALYSIS OF VALVE-SPRING VIBRATIONS

The Heavy Line in Each Graph Represents the Resultant Stress-wave Composed of the Fundamental Wave A and the Reflected Wave of Double the Amplitude of A Occurring at Phase Intervals of $2l$. The Broken Lines Illustrate the Method of Constructing This Resultant Wave Graphically

on that of the initial wave A. The reflected waves surge repeatedly from end to end of the spring and combine with one another either to damp out or to augment the effective stress in the wire. The cumulative effect is plotted by adding the individual waves in their proper phase relations.

The upper graph in Fig. 1 was derived for a camshaft speed of 625 r.p.m. The valve is open for 0.032 sec., and the length vt therefore represents 320 in. But $2l$ is 100 in., so that 3.2 waves are traveling through the spring while the valve is open. As the resultant vibrations in the spring are damped only by the elastic hysteresis of the metal, they may be expected to continue with little diminution until the valve is again opened. These vibrations are represented for a complete cylinder cycle by the heavy line, plotted on the normal deflection of the spring in the closed-valve position.

The intermediate graph corresponds to a camshaft speed of 1000 r.p.m. The length vt is 200 in., which is exactly double two spring-lengths. Fewer waves traverse the spring, and their amplitude is greater than those at 625 r.p.m.

[10] See the S.A.E. JOURNAL, November, 1928, p. 461.

[11] M.S.A.E.—Research engineer, Studebaker Corp., South Bend, Ind.

In the lower graph the camshaft speed of 2000 r.p.m. allows the valve to remain open for only 0.01 sec., which synchronizes with the wave period in the spring. A resonant condition is developed; and the vibrations while the valve is seated are those of the full reflected stress-wave, which is double the initial stress-wave.

MR. JEHLE:—We are somewhat familiar with the analysis given by Mr. Huebotter, having first seen it in W. R. Griswold's paper[10] given at the Semi-Annual Meeting in 1928. It does not seem to us that this wave theory agrees with the harmonic theory, which was supported by experiment, in the following points:

(1) It assumes that all spring waves start with the beginning of valve lift, whereas the test records show that the maximum amplitude of the wave occurs at the center of the valve lift

(2) It concludes that the amplitude of vibration increases in proportion to the speed, whereas experiment shows that vibration may be greater at a lower speed

(3) It requires that the valve-open period must be 120 deg., or some even divisor of 360 deg., if a resonant condition is to be produced

If this interpretation is incorrect, the authors will welcome further explanation.

WILLIAM S. JAMES[11]:—Last night I heard a very interesting talk by Prof. George L. Clark, of the University of Illinois, on the application of X-rays to industry. Among other things, he reported that in drawn wire the crystals align themselves in one direction, and in rolled sheets they are oriented in another direction. He therefore had the idea that, if you "fool" the molecules by drawing and rolling the sheets at the same time, it would not be necessary to anneal after the operations. He said that this had been tried and was found to be successful.

Have X-rays been considered for the examination of defects in spring wire; or has the suggestion made by Professor Clark of "fooling" the molecules when the wire is both drawn and rolled at the same time received any consideration in connection with valve-spring wire?

MR. WOOD:—A great deal of study has been given to the use of amplification of X-rays in looking for defects and also looking for what constitutes proper crystal structure in steel. How far that has gone in individual cases for valve-spring wire I cannot say. I know of only one case in which a steel manufacturer actually is, or at least was a year ago, carrying on work in this exact connection. Nothing has been published in regard to the results of those examinations, and I imagine that they are still in a formative condition.

MR. DONKIN:—We have tried to inspect valve-springs by magnetic analysis; but the defects that are really dangerous for valve-springs are the defects which are in the direction of the axis of the wire, and magnetic analysis does not seem to be able to detect that type of defect. We obtain a very positive reading from a transverse defect, but defects in the longitudinal direction slip through and we cannot catch them by magnetic analysis as yet. However, work is still being done on this problem.

We are undertaking some tests on springs made from wire in which a combination of drawing and rolling, similar to what Mr. James suggests, has been tried. The results, however, have not been confirmed, and we are not ready to report on the tests until we can come to a more positive conclusion.

Recent Progress in Automobile Design

> **The Research Department has been fortunate again this year in obtaining Austin M. Wolf's[1] critical survey covering the advances made during 1928 in the various phases of automotive research and design. Mr. Wolf presents in a simple, direct style his observations and opinions based on a long experience in the automotive-engineering field.**
>
> **This article, written for and appearing in the American Year Book, is used here through the courtesy of that publication.**

THE year 1928 will be recalled in future years as marking the last stand of the four-cylinder passenger-car engine, with only one large manufacturer adhering to it at the close of the year. The six-cylinder engine has crept into the low-price class. Improved appearance of the entire vehicle, de luxe cabs and six-wheelers mark the motor-truck field. The all-metal sleeping car, with accommodations for 26 passengers and provided with kitchen and lavatory, is the surprise of the year from the motor-coach world.

ENGINES

The straight-eight engine has gained in favor to the extent of its sole production by two manufacturers. Its flexibility and acceleration have won public favor. Increases in engine bores are numerous, with the aim of greater power. This is usually accompanied by greater valve diameter or lift, or both. Added power has not only increased dimensional and other changes in the engine itself, such as sturdier front drives and more rigid camshafts and crankshafts, but in many parts of the car through which the power is transmitted to the rear wheels.

Compression ratios are still rising, reaching a maximum of 6.2 to 1 for use with special fuels. For standard fuels we find engines with 5.2 to 1, 5.3 to 1 and 5.55 to 1 as top-notch ratios, the last being on the border line. Comparatively short strokes, in relation to the bore, appear in some of the newer engines.

Aluminum piston types are increasing in variety. Reversion to cast iron by a former user is to be noted, in the change from a four to a six. Stiffening the bottom of piston skirts is in evidence. Piston-pins, in one case, are made a tight press-fit on the setscrew side and a push-fit on the other side to allow free expansion. The modern valve has been developed to a point where it is remarkably free from trouble, the problem devolving upon the seat.

An opinion is crystalizing that the shape of an I-section rod assumed after heat-treating is its permanent form, and any subsequent straightening would only be momentary once the rod is placed under the stresses of service. For this reason, tool equipment and methods are provided which eliminate any strain during machining operations. In heavy-duty high-speed work, pounding out of the babbitt in the big end has presented a problem. Redesigning of the big end has aimed to keep the babbitt from cracking. Other than the bond provided by tinning, mechanical strength is obtained by dovetailing the babbitt into the rod at each side.

Larger crankshafts are used. Steel-backed babbitt-lined interchangeable main bearings and caps are in vogue. Crankpins smaller in diameter than the main bearings are claimed to raise the critical speed of torsional vibration and, combined with the smaller connecting-rod big end, cause considerable reduction of the centrifugal forces on the shaft. A vibration damper consisting of a light metal disc accurately balanced and mounted on specially prepared rubber discs has been introduced.

Increased oil capacity in the sump and larger oil-pumps are found in the new engines. Oil-pressure-relief valves of the ball type are being replaced by plungers to secure quieter action. A button on the dash which cannot be pulled out when the sump is full, and indicating by the extent of its protrusion the drop in oil level, is a new type oil-depth gage operative from the seat at any time. Top cylinder-lubricators are being given consideration.

Crankcase ventilation is now provided with manual control. Despite the return of one maker to rigid metallic supports, rubber engine-mountings are being developed to greater refinement. A chief aim is to provide a unit type so that engine removal will not dismantle the rubber and furthermore that it will be impossible to increase its compression by taking up on the mounting bolts. One mounting consists of rubber vulcanized between several steel plates, using the rubber in tension rather than compression.

Twin ignition has been revived, and in this case two breakers are actuated by the same cam, two coils feeding a double arm which distributes the high-tension current to terminals in a 12-point cap. Metric plugs, being smaller than the standard, are used to avoid heating troubles and allow slightly increased jacketing around the plug boss.

COOLING

The cross-flow radiator is an innovation of the year. Finer core cells increase the radiator volumetric and heat-dissipating capacity. Built-in thermostats operating vertical radiator shutters are popular. Improved fastening means for the radiator caps are to be seen. In several cases the water-pump has been removed from the front of the cylinder-block to the side of the engine. Pump packing between the impeller and the bushing mitigates leakage. One fan is provided with an automatic clutch which disengages the fan at a car speed of 35 m.p.h. The fan of the self-oiling type, having a gear-pump incorporated within the hub, is considerably used.

FUEL SYSTEM AND MANIFOLDING

Coincident with the expiration of the basic patent on vacuum tanks, a diversity of systems have come to light besides such improvements in the tank as the booster. The electric fuel-pump principle has been ex-

[1] M.S.A.E.—Automotive consulting engineer, Newark, N. J.

tended to a pumping unit located in the supply tank and also incorporated in the carbureter, replacing the float chamber. One system consists of atomization of the fuel in the supply tank, making a rich mixture and diluting it at the engine manifold. An interesting innovation is the insulating of the carbureter from the manifold to prevent any otherwise conducted heat from vaporizing any light fractions of fuel within the carbureter.

Protection of the exhaust manifold from frame distortion is provided by a short section of flexible tubing in the exhaust pipe. Where sheet asbestos was formerly used, the exhaust pipe is now covered with molded asbestos. One muffler is asbestos-covered and bolted directly to the frame cross-member. Another muffler installation making for more silent operation consists in securing the front end directly to the powerplant while the tail pipe supports the rear end.

Clutch

Clutch developments are found in easy engagement, dissipation of heat and absorption of vibration. Clutch plates are given a slight wave to soften the action. One clutch ring is split into 12 segments, alternate ones being offset in opposite directions, and the molded composition facings are riveted to alternate segments. For truck use a double-disc construction is used, with thick driving plates to increase the rate of heat-flow. The discs have individual hubs, the rear-disc hub being piloted on the splined outside diameter of the front hub. A new resilient drive consists of a square-section rubber strip mounted in compression between a triangular hub and a rim on the driven plate, the former floating in relation to the latter and being angularly restricted by the rubber.

Transmission

Foremost in the year's innovations is the synchromesh transmission, whose chief virtue lies in the ease of shifting up or down between intermediate and high. In some cases shaft center-distances have been increased, permitting the use of larger gears. Control levers are placed farther forward. In several instances the gearshift lever is mounted on the clutch-housing plate, giving greater room.

Universal Joint

A pressure-relief valve incorporated in the center pin of the joint allows breathing action for the displacement of air caused by movement of the slip-joint. When not running, this valve is submerged in oil and, if lubricant is forced in under pressure, the valve opens and allows oil to escape when a certain pressure and oil level is reached due to the air-bell effect of the entrained air.

Rear Axle

Sturdier axle construction was brought about to lessen rear-end noises. Furthermore, the increased engine-output and high vehicle-speeds have required it. Thus, the paradoxical situation exists of the unsprung weight being increased through necessity in spite of all desires in the opposite direction for better riding-qualities. The problem of keeping axles quiet in the field is vital, particularly today when engine and other noises are at the minimum.

The special shaping of the cover-plate, or the attaching of a trough thereto, assists in the lubrication of the differential gears by directing or deflecting the flow of lubricant. Chromium-plated differential pins have appeared. Axle shafts have been enlarged in diameter because of increased torque.

A hypoid-bevel-gear final drive has been introduced in truck work, with the pinion mounted above the axle. Spiral-bevel-gear axles are available for trucks up to $2\frac{1}{2}$-ton capacity. Cast-steel housings are coming back again, replacing the welded pressed-steel type. Tracks have been increased to take care of dual-tire mounting. The truck field is taking a decided stand on full-floating axles.

Brakes

Many makers have found it desirable to have a slight excess of braking action on the front wheels. One car fitted with hydraulic brakes uses at the front a brake cylinder $\frac{1}{8}$ in. larger in diameter than the cyilnder at the rear. A mechanical four-wheel-brake system uses a 55-45 front-and-rear ratio.

Drum concentricity is essential and is readily obtained by the use of eccentric anchor-pins. A trend away from the customary anchor-pin mounting is to be found in a new internal brake which, while having a short shoe with a direct or customary anchor, has a long shoe with self-energizing effect connected to its anchor-pin by a pair of links. This provides for self-centering and immediate full contact.

Sturdier drums are being used, by increasing the stock thickness. A new brake-drum material has been introduced, being a graphitic steel showing pearlite in its microstructure. One passenger-car has a coiled spring mounted around the outside of the drum for silencing the brake, and it has been found to aid cooling.

Stiffened brake-linkage, such as cross-shafts and levers, averts distortion. Cross-shafts are supported in ball-and-socket bearings to prevent binding caused by frame weave. To reduce friction to the minimum, roller bearings are used to support camshafts and cross-shafts. Closer adjusting means are provided on the camshafts.

Front Axle

Sturdier designs are seen, and I-beam sections, spindle diameters and wheel-bearing sizes have been increased in many instances. Knuckle pins have increased in diameter and the bushings in thickness. Larger tie-rods maintain greater rigidity. For this reason, offsets are avoided. Front-wheel drives are being tested out, and one maker will shortly introduce a model incorporating such a drive.

Wheels and Tires

Wooden wheels have spokes of elliptic section to give more massive appearance while retaining lightness. Hubs and hub-caps are larger. With a plain, large, round hub-cap, a strap wrench is used for its removal. The users of small-diameter wheels increase. One maker has given up the balance lugs formerly used. Dual pneumatic truck tires are replacing the large, single rear tire formerly used. Realizing the difference in operating conditions, such as medium speed and normal daily mileage as compared with intercity service and large mileage, two types of tires have been developed for passenger cars, trucks and motorcoaches to meet these varying conditions.

Suspension

Foremost in suspension improvements is the double shackling of the front spring on the steering-gear side so as to reduce "wheel fight." The otherwise fixed rear eye of the spring is supported in a trunnion or yoke, which is retained in a neutral position by opposing coil springs which yield under and absorb road shock without its being transmitted to the steering-gear. To dampen out oscillations, interleaf friction is increased by holding, by means of the spring clips, a short reverse-cambered leaf against the main leaf near each end of the spring. Spring periods have been reduced to give a softer ride. Independent wheel suspension is being thoroughly investigated as one means of improving riding qualities.

Frame

Increase in section modulus in frame members is obtained by the further flanging of the otherwise plain channel section. Side-rails are provided with downward extensions from the lower flange, while one maker has an upper flange turned up for some distance fore and aft of the front kick-up. There is a considerable vogue for widened cross-members with the webs horizontal and a horizontally outward extension to each flange. An end-fitting usually braces the cross-member to the other side-rail flange from the one to which the member is directly fastened. Front cross-members have been made of box form to give the front end torsional rigidity.

Control

The variable steering-gear ratio has been replaced by a constant low ratio in a number of cases. The flat type of steering-wheel of hard molded rubber over a flexible steel core is common practice. The left-hand brake-lever location is growing. Gearshift levers are closer to the wheel, being within 4 in. in one case.

Equipment

Headlights are larger, usually bullet-shaped, and their location is not only utilitarian but in keeping with beauty. A practical photometric testing-stand developed to check beam patterns and light intensity ensures compliance with the legal requirements and assures adequate light for safe driving. Cowl lights have been moved, in one instance, to the front fender, serving as parking lights.

Instrument panels are found in varied artistic finishes. Direct or indirect illumination, as desired, can be furnished by a three-way toggle-switch. Gages, in one instance, are of the revolving-dial type similar to speedometers, with the panel so designed and lighted as to be easily read from the back seat. Clearance lights, or, in their stead, light-reflectors, are required by one State law, to show the extreme vehicle width when this exceeds 80 in. The elimination of all junction boxes and conduits in favor of an armored and rubber-covered-cable system is to be noted; also, the abandonment of the circuit breaker in favor of a fuse and ballast coil.

A dash-operated lock automatically operates on the transmission if the connecting cable is cut. The tandem-blade windshield wiper is a welcome improvement. Open-car windshield wings have been developed the full length of the front door. The plain, straight bumper is obsolete, in the endeavor to kill all hard lines that might detract from the body and car ensemble. The convex bar is popular. An improved rebound-checking mechanism of the friction type utilizes in the braking member a rubber-like material which provides a "flowing" action over the polished steel drum. Great strides have been made with the hydraulic type of shock-absorber They are usually double acting and have a free center. A cushion of air is sometimes used for the central free zone. One car is provided with a built-in system in which the shock-absorber is mounted on brackets forged integral with the front axle, the link arms being connected directly to the frame where the ball-and-socket joint is supplied by the chassis lubricating system.

Sheet Metal and Body

Wider and more sweeping fenders are the vogue, various raised designs being incorporated in the tips. The long fenders result in shortened running-boards. Headlight tie-rods have been beautified, one design being arched and chromium-plated, with gracefully bifurcated fender anchorages. Radiators and hoods are high. Vertical center bars appear in some radiators. The narrow-rim radiator brings the hood up to nearly the front, a cutaway being provided for the filler-cap. Others provide a narrow shell as viewed from the front but massive from the side. A false radiator-header incorporated in the shell gives the appearance of the continuation of the shutters or of the core.

All body changes aim to improve appearance or comfort. Arched windows which are slightly curved at the top to contrast with the curve of the top rail are used. Straight lines are taboo, even in the rear window. A popular belt is one that merges forward of the windshield pillar into a bead on the hood and unites with another at the base of the windshield. The elimination of all belt moldings, combined with a belled-out panel where the belt rail would be, is one of the year's sensations. It is designed to catch the highlights in long horizontal lines in lieu of a belt. An entire body side, die-formed in a single piece, is an accomplishment of the year. Shims of molded live rubber are used for body mountings. A spring-loaded bolt for the front body mounting near the dash provides some flexibility at this point.

Wider doors and general increase of interior dimensions ensure comfort. Lighter-gage or longer spring-coils are used to improve the cushioning. Great care is used in sealing the front compartment against drafts in winter, and ventilation in warm weather is provided by cowl louvres or foot-operated ventilators at each side. To insulate the front compartment from noise and heat, we find the dash not only ribbed to prevent drumming but lined with fiber-composition panels, felt padding, celotex, or hair pads. Floor-boards are wrapped in fabric or provided with a lower side-covering to mitigate noise transmission.

Success of the convertible coupé has spurred makers on to the convertible phaeton-sedan, which is a promising and growing development. The victoria bow, formerly an ornament, is now put to use, providing a folding rear quarter. Colors no longer run riot but are more subdued. Color is used to emphasize the line design and to carry out the long, low, rakish appearance spelling sturdiness and speed. The influence of modern art is felt in both the interior and exterior treatment of today's cars.

Transportation Engineering

Chassis-Record Forms

Subcommittee Recommends Compilation and Maintenance of Standard System for Chassis Parts

MEANS for compiling a standard system whereby data on the mechanical parts of motor-vehicle chassis will be recorded on a standard record form at the time the information is obtained, and provision for maintaining this system, were the subjects investigated during the last year by Subcommittee No. 1 of the 1928 Operation and Maintenance Committee of the Society.

The success of such a system is dependent upon proper initiative on the part of the manufacturer in sending out data regarding changes made, and upon how well the details of its application can be worked out. But with such a standard system in effective operation, it is believed that the service stations and the motor-vehicle-fleet operators will be afforded an immediate and reliable check on changes made by the manufacturers of the vehicles they operate, and that the records can be used with certainty in properly specifying replacement parts. The following report of the work already accomplished was submitted by J. F. Winchester, Chairman of the Subcommittee, at the Transportation Meeting held in Newark, N. J., Oct. 18, 1928.

Report of Subcommittee No. 1

Reporting upon the work that has been accomplished in the development of a Standard Chassis-Record Form, a complete specification-sheet was designed along the lines of one that has been in use for a long time within the transport organization of the Standard Oil Co. of New Jersey. This form did not originate with our organization. It was given to our company by a large-scale manufacturer of motor-trucks, and we have found it indispensable in the operation of our equipment.

Having in mind the fact that such a form has been in constant successful use, and that with a few slight changes it would answer the requirements of the membership as a whole, the proposal that it be used generally was submitted to the membership through the S. A. E. JOURNAL, July, 1928, p. 120, and a ready response was made by a large number of interested members. In addition, a number of sample record-sheets that are used by various companies throughout the Country were received. These samples are good within themselves; but they illustrate the desirability of standardization, as has been suggested.

The following list includes the names of men from whom criticisms have been received, classified into three groups according to their views. Those who favor adoption of the chassis-record form are listed in the first group; those who think the form is undesirable or impracticable, in the second; and those who hold a neutral position, in the third.

FAVORABLE

F. C. Horner, assistant to vice-president, General Motors Corp., New York City.

T. L. Preble, assistant general manager, Brockway Motor Truck Corp., New York City.

L. J. Heinrich, service manager, Autocar Sales & Service Co., Inc., New York City.

H. A. McKim, superintendent of motor equipment, Standard Oil Co. of California, San Francisco.

L. V. Newton, mechanical engineer, Byllesby Engineering & Management Corp., Chicago, Ill.

A. L. Douglas, branch manager, Mack-International Motor Truck Corp., Atlantic City, N. J.

J. S. Dagilaitis, district service manager, White Motor Co., Kansas City, Mo.

Donald Blanchard, editor, *Operation and Maintenance*, Chilton Class Journal Co., Philadelphia.

George Barker, service representative, General Motors Truck Co., New York City.

E. C. Wood, superintendent, transportation department, San Francisco division, Pacific Gas & Electric Co., San Francisco.

Eugene Power, manager, properties, facilities, Union Oil Co. of California, Los Angeles.

H. L. Wright, service manager, White Motor Co., Long Island City, N. Y.

UNFAVORABLE

C. A. Borton, general manager, Autocar Sales & Service Co., Boston.

J. W. Florida, service manager, Packard Motor Car Co. of New York, Long Island City, N. Y.

A. J. Scaife, chief field service engineer, White Motor Co., Cleveland.

W. F. Banks, president, Motor Haulage Co., Inc., Brooklyn, N. Y.

NEUTRAL

A. W. Scarratt, chief engineer, motor-truck engineering, International Harvester Co., Chicago.

G. P. Anderson, director of sales engineering, Dodge Bros., Detroit.

B. B. Bachman, chief engineer, The Autocar Co., Ardmore, Pa.

W. R. Gordon, sales engineer, Pierce-Arrow Motor Car Co., Buffalo.

Ethelbert Favary, consulting engineer, manager sales promotion, Moreland Motor Truck Co., Los Angeles.

The comments made by the men mentioned will be helpful to the Committee as a whole. It is impracticable to review all the comments in detail, but I feel it advisable to bring out points in connection with those that are not in favor of standardization of this kind.

Certain ones of those who comment adversely say that the Manufacturers' Chassis-Parts Book, which accompanies each truck sold, covers in detail all the information it is necessary for an operator to have. According to my view, the manufacturer has done a very good work in getting out this book; on the other hand, no provision is made to give in the book an exact indication of the type of equipment supplied with any individual truck. For instance, if an operator breaks a side-rail, he cannot order it direct from the Parts Book without going to the trouble to measure the wheelbase of the truck.

Various units for different classes of work, as is well known, vary in detail as regards the combination of gears in the transmission or the rear axle. The Parts Book in no way indicates what combination is placed in a given unit. Equipment is sold in many instances along special lines. If it were possible to secure an actual analysis of the special jobs that pass through any of the shops, it would be found that the percentage of this business is very large; for there is no question that most builders are manufacturing to specifications, rather than producing their own standard units.

RECORDS AND MARKING METHODS

One operator has made a direct criticism, and another indirectly suggests, that a record of this type would prove costly because it necessitates additional clerical detail. From my viewpoint this is a short-sighted stand to take, as the data given with any specific type of truck are not carried through to a logical conclusion at present. In his comments, W. F. Banks particularly states that it would be possible to identify the parts number by giving it on each part that makes up a vehicle. Those of us who have had extensive experience with foundry marking of castings know that the marks often

are obliterated or difficult to identify. Moreover, this method of marking does not indicate the combination of parts in any given unit and, in addition, makes no provision for changing the markings if the ratio of combinations in the unit are changed. Mr. Banks states further:

> Loss of identification, Mr. Winchester claims, costs fleet operators and service stations thousands of dollars. No doubt this is true, but the information is available if properly taken care of. His proposed Final Chassis Record does not include anything that is not already available with reputable manufacturers. It revolves itself around the same old story—human equation and lack of proper supervision.

The fact that this information is not available can readily be attested by referring to the comments of some of the reputable manufacturers, who state that they do not keep any detailed record of any type. On the other hand, if all of the manufacturers did maintain a record of this kind, standardization of it would be of great assistance to the industry as a whole; it would assure the operator of getting the proper record, and in such form that he always would know where to refer readily to the desired information. As to the human equation and lack of proper supervision, this matter was covered fully in the original survey. The whole idea was evolved to make the problem more simple, so that less supervision would be needed, and this tends to solve the problem of the human equation.

C. A. Borton and A. J. Scaife both indicate that the information should be kept by the manufacturer, but question whether the operator should have it available. These two comments, together with others that have been received, indicate that a standard record of this kind is of direct benefit to the manufacturer. If we take into consideration the suggestions of those favoring the Final Chassis Record, it can be seen that many of those in the manufacturing end favor its use.

Summing up the situation as a whole, I feel that distinct progress has been made during the year, and that during the coming year two or three Committee meetings should iron out the subject completely. Further, I feel that it is a question of proper procedure within the Society as to how the Final Chassis Record can be formally adopted as another S. A. E. Standard.

Should the work be carried on by the Operation Committee as a unit? Should it be carried on by the Standardization Section? Or should a Committee be appointed to act as a representative of each group, so that, when the work is completed, it can be submitted and adopted as a standard?

J. F. WINCHESTER,
Chairman.

Highway-Transport Problems

Clarkson Advocates Railroad and Automotive Organization Cooperation for Their Solution[1]

TWO years ago, at a Transportation Meeting of the Society of Automotive Engineers held in Boston, a resolution was passed calling for the establishing of a joint committee of the railroad and the automotive industries to study fundamentals of motor-truck operation such as coordination of involved phases of rail and highway transportation, operating organization, and necessary engineering standardization. The subject was introduced by railroad men present at that meeting, and representatives of various railroad companies served on the committee that formulated the resolution. The members of the proposed committee were to represent the Motor Transport Division of the American Railway Association, the National Automobile Chamber of Commerce, and the Society of Automotive Engineers. Those from the automotive industry were to be predominatingly men of the operating type.

Thinking well of the plan, the National Automobile Chamber of Commerce and the Society of Automotive Engineers named members to serve on the committee; but, on the railroad side, representatives were not named.

No doubt there are adequate reasons for the railroads not having followed up the proposal for the joint committee. We hope for action agreeable to them in due course. We know that procedure outlined in some programs is not practical, as well as that at times programs in which practical procedure is outlined are not followed. Conditions change, and change rapidly, in new developments. Doubtless there will be some difficulty in getting a good working program.

Need for Joint Research

It seems clear that some joint studies should be made by representatives of the railroad and the automotive industries. Practical sense is the source of all progress. Definite lines of conduct obviate confusion. So far as may be, we should place the various matters in their proper rank. Practical sense has been defined as doing that very thing. Such a science deserves to be cultivated. With attention and analysis, we can find answers we need that cannot be secured in any other way. What can be done by joint work is, of course, limited in various ways, but many things can be done in no other way.

There is no substitute for individual ability. In competition, the best men and companies ultimately win. But much is to be gained by cooperation. Our industry knows this from experience. In cooperation, each group, naturally, keeps keenly in mind its own interest.

It is easy to criticise. And the less one knows of a subject, the easier it is to criticize. To make necessary extensions and improvements, public-utility companies must have reasonable returns on their capital. Without return capital will not be furnished. But the successful railroad will have to have uptodate equipment on highway as well as on rail.

The original development of the railroads was due largely, if not entirely, to the fact that at the time there was no suitable equipment or road system for large-scale highway-transportation. And no such equipment was in sight; nor, for that matter, was there a highway system in sight in this Country. Now, we have equipment suitable for handling much highway transportation, and, because of its various advantages, utilization of it is growing rapidly throughout the world. Like a moral force, the fundamental of all forces, highway transportation is advancing inexorably. Given the roads and the equipment, the reason for this has existed all along. Of course, we are entering now the phase of great highway-transportation systems. Road building in this Country has only begun.

Scores of railroads are now operating motorcoaches over hundreds of routes aggregating tens of thousands of miles. They are using thousands of motor-trucks, tractors and trailers. This movement also has only begun.

What Work for Road and for Rail?

The proper work to be done by road vehicle and by rail equipment, respectively, remains to be settled. The condition is one of marked change, just as it was when railroad development began. And it is just as true today as it ever was that, for efficient operation of any form of transportation, physical environment must be studied, as well as equipment and management, operating and maintenance practices.

For several years the Society of Automotive Engineers has maintained activities, Nationally and locally, concerned specifically with road-transport problems. Many hundreds of the

[1] Address delivered Oct. 26, 1928, at a meeting of the Motor-Transport Division of the American Railway Association in Detroit.

Society members are directly interested in motor-vehicle-fleet operation, maintenance and service. They have organized their own Division to work on problems relating to motor-vehicle-cost determination, man-power in the shop and in the field, accessory equipment, research, standardization, and governmental regulations so far as they involve engineering features. The Society as a whole is constituted of men engaged throughout the world in the design, production, operation and maintenance of motor-vehicles. In addition, its membership includes many research men and men engaged in the production of parts, materials and components, and all commodities used in producing motor-vehicles. Studies of great variety are being made continuously.

The operation and maintenance work of later years supplements, as well as connects with and is supported by, all of the standardization, research and joint engineering work that has been centered in the S.A.E. for more than 20 years. Also, the Society is in close contact with the trade associations of the whole automotive field.

The Society will be glad to be as helpful as it can be in studying engineering and related problems common to the railroad and the automotive industries. There is great need for further organized effort. In our field, progressive action is yet to be taken on many major matters that will have to be handled. The railroad men can help greatly. We certainly hope to become better acquainted with them.

C. F. Clarkson.

Discussion of Cost Accounting

Discussion of the paper by G. R. Gwynne, of the Continental Oil Co., Denver, Colo., entitled Motor-Vehicle Cost-Accounting and Its Relationship to Economical Fleet Operation, which was presented before the American Petroleum Institute at its December, 1928, meeting, centered upon means whereby standard practice with regard to cost accounting can be accomplished. J. F. Winchester, of the Standard Oil Co. of New Jersey, mentioned the magnitude of the task as evidenced by the mass of data already accumulated by the Society of Automotive Engineers in its previous work on cost accounting, which work is being continued. At present, he said, no fundamental basis exists for comparison of costs, and his desire is that the problem be reduced to a basis which will enable comparisons to be made.

H. A. McKim, of the Standard Oil Co. of California, said that the records of his company are kept with regard to operating areas. Trucks are considered as a group, truck and passenger-car charges are included in the group, and no individual unit-records are kept. This practice resulted from the failure of a very complete unit-cost-accounting record because of the difficulty in securing accurate figures, correct assignment of time and parts charges, and accurate mileage statistics. Mr. McKim said that the mechanics are not "bookkeepers," the accountants had difficulty in segregating charges properly because they are not specialists in automotive work, and difficulty was experienced in keeping odometers in continuous operation. In his opinion, the company has a better estimate of individual makes of truck by observation of their performance throughout their life than can be obtained from a survey of a cost record. Mr. McKim said that the present practice of keeping no individual-unit records of the fleet is perhaps revolutionary.

Standard System Believed Feasible

R. E. Plimpton, of *Bus Transportation*, referred to the report on cost accounting made by L. V. Newton at the Society's Transportation Meeting in October, 1928, as constituting merely a start toward the attainment of a standard cost-accounting system, and said that it is hoped that this report will be referred to various associations so that its fundamentals can be studied and, through the advice and help of all concerned, a system devised which will be useful to all. He said that the petroleum industry, utility services, commercial carriers, and distributors of small-package goods should be included in the movement.

L. V. Newton, of the Byllesby Engineering & Management Corp., stated his belief that bookkeeping is necessary and that simple bookkeeping is not expensive. He hopes that his report, which was printed in the December, 1928, issue of the S. A. E. Journal, beginning on p. 625, will be used as a guide in the study of cost accounting.

F. C. Horner, of the General Motors Corp., and Chairman of the Society's 1929 Transportation Committee, said that it will be a long, hard job to arrive at any practical and satisfactory conclusion as to what factors in cost keeping are comparable, but that this can be done. He believes that certain fundamental things can be agreed upon if those interested make up their minds to do so.

A. F. Masury, of the International Motor Co., stated his belief that direct cost per mile is an equitable basis on which to rate the operating cost of vehicles.

A. J. Scaife, of the White Motor Co., expressed the opinion that the main interest of truck manufacturers lies in how much it costs to carry products from the manufacturing plant to the consumer and that, therefore, there is vital interest in having a uniform system or method of measuring costs.

Transportation-Committee Meeting

A meeting of members of the Transportation Committee who reside in New York City and vicinity was held Feb. 4. Chairman F. C. Horner presided, and the discussion centered on matters concerning meetings of the Society.

On the recommendation of the Truck Committee of the National Automobile Chamber of Commerce, as stated by E. F. Loomis, the directors of the Chamber have voted to conduct a National Commercial-Vehicle Show in the Middle West, probably late in 1929, at which ample space will be provided for all types of truck, motorcoach, taxicab, delivery-wagon and special-apparatus vehicle. A number of makers have pledged themselves to participate, and it is planned to hold a National Transportation Convention by the Chamber at the same time.

It was decided to take a letter-ballot of all the Committee members as to whether to continue planning to hold the Society's National Transportation Meeting in the spring or to hold it in the late fall in conjunction with the N. A. C. C. Commercial-Vehicle Show.

Subjects suggested for the National Transportation Meeting papers, exclusive of reports from Subcommittees, were six-wheel-truck and truck-and-trailer operation and maintenance, including fifth-wheel connections and hitches; operation and maintenance of electric trucks and industrial trucks, with special reference to the operation and maintenance of electric controllers; house-to-house delivery by motor-truck; light-alloy all-metal-body construction, including cabs and tank bodies; and horse-drawn vehicles versus motor-trucks in a given service.

Papers planned for the Transportation Session of the 1929 Semi-Annual Meeting are on the subjects of Long-Distance Motorcoach Operation, Heavy-Freight Haulage, and Package-Delivery Service.

Papers on Transportation

An interesting paper on Profitable Motorcoach Operation, by R. N. Graham, of the Penn-Ohio Railway Co., Youngstown, Ohio, is printed in this issue beginning on p. 278.

The respective merits of molded and of woven brake-linings are presented in the symposium which begins on p. 295.

Production Engineering

Casting Steel Axle-Housings[1]

How the Electric Furnace Was Adapted to the Needs of a Small Steel Foundry

DURING the war, when it was difficult to obtain steel castings from the East, the company with which I am connected built its own electric furnaces from specifications furnished by C. H. Vom Bauer. A direct arc is used with non-conducting hearth in this type of furnace; and we employed three-phase alternating current, with three carbons entering the furnace. The furnace shown in Fig. 1 has a capacity of 3 tons, and is provided with automatic regulation of the arc. The smaller furnace has a capacity of 1½ tons, and is hand regulated.

The electric process offers several distinct advantages: It is flexible and very well suited for the manufacture of castings; the temperature can be controlled within close limits; the deoxidation and reduction can be as thorough as desired, and phosphorus and sulphur can be eliminated as completely as necessary. In the acid process the phosphorus is controlled by purchasing scrap of known phosphorus content, and deoxidation ensures desulphurization. Electrically produced steel has great density and can be made free from blow-holes, from slag and from absorbed gases; it is strong, tough and ductile. To produce nickel-steel castings, the nickel alloy is added directly to the molten metal before it is transferred to the ladle.

Because of the low electric rates on the Pacific Coast, the cost of current for small furnaces is very low indeed. It is necessary, however, to have a man in charge who has a thorough knowledge of the electric-furnace method. To produce good sound steel it is absolutely necessary that the metal does not contain impurities, oxides or gases.

For the production of castings the electric process offers great advantages, because a high temperature is easily obtainable. This reduces the scrap loss encountered with other systems, and the furnace can be used for the production of both iron and steel castings. Also, hot metal is necessary to run thin sections when outlines must be sharply maintained.

In the acid process, only three elements must be considered to assure good castings. These are carbon, manganese and silicon. Sulphur and phosphorus, the two most undesirable elements, are not affected by refining; they need not be considered, as they are taken care of automatically.

Since the oxygen is introduced as rust or scale on the scrap-iron used, and later with ore, the silicon and the manganese become manganese silicate, upon being oxidized, and enter the slag. The carbon is oxidized to carbon monoxide and escapes as a gas. The deoxidizing process does not have to be carried so far in the acid-type furnaces as in others. The iron-oxide content is lowered to a point where it meets practical conditions. The deoxidizing agents used are manganese, in the form of ferromanganese; silicon, in the form of ferrosilicon; and carbon titanium, which is a prepared compound. By using the latter instead of pure aluminum, we find that the tensile strength and the elongation and reduction in area are greatly improved. The silicon should be added first, well before tap, and the manganese later. Silicon is not only a deoxidizer; it is efficient as a degasifier.

As a refractory material for the roof and the side walls of the furnace above the slag line we now use vitrified brick. Formerly we used silica brick. Below the slag line we use silica brick and silica sand sintered by the electric arc. We find that the best refractory materials are the cheapest in the end.

We pay the utmost attention to the raw material which we purchase, and use scrap only of a predetermined analysis. Rust, if excessive, is eliminated by tumbling.

Manufacturing Axle Housings

When the company first began to produce axle housings for its six-wheel trucks, several difficulties were encountered. I shall mention them for the benefit of others who may wish to produce complicated castings.

In the first samples, which were made as shown in Fig. 2, we found shrinkage cracks in the corners at *a*, *b* and *c*. These cracks developed because of the greater mass of metal at these places, which adversely affected uniform cooling. To overcome the trouble at *a* and *b*, the first step was to add extra metal to the corners, as shown in Fig. 3, which was afterward turned off. To still more effectively eliminate cracks, metal chills *d* were added, as shown in Fig. 2, but at present the metal chills have been eliminated and a softer core, obtained by means of a

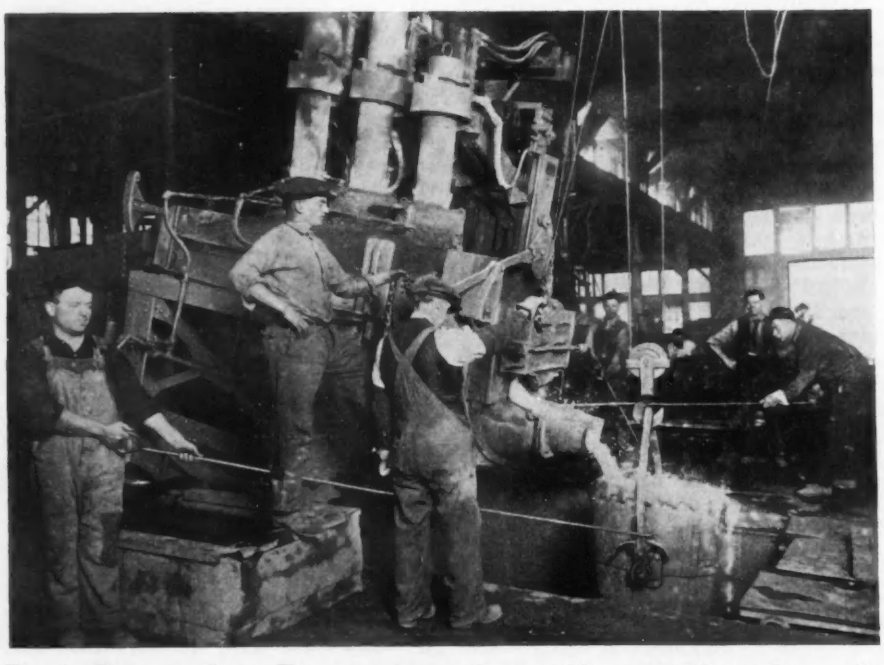


FIG. 1—ELECTRIC STEEL FURNACE, 2 TO 3 TON, IN MORELAND MOTOR TRUCK CO. FOUNDRY

[1] Paper read by Ethelbert Favary, M.S.A.E., consulting engineer of the Moreland Motor Truck Co., Los Angeles, at the joint meeting of the Southern California Section and the Western Metal Congress.

softer binder for the sand, is used instead. The shrinking cracks at *c* were more difficult to overcome, and we had to eliminate the circumferential ribs and extend the longitudinal ribs, as shown at *e*. The small ring *f*, attached to the ribs instead of to the outer shell, does not influence the shrinkage of the housing. Thus a sound casting is produced, free from cracks. The ring is necessary to support the end of the chromium-nickel-steel tube which supports the wheel bearings.

In these castings we use about 0.30 to 0.31 per cent of carbon, and 1 per cent of nickel is added to the bath. As

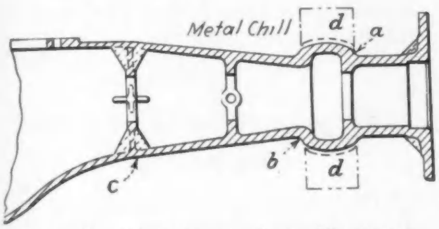


FIG. 2—CAST-STEEL AXLE-HOUSING WHICH CRACKED

soon as the castings are poured they are withdrawn from the mold, the cores removed, then permitted to cool slowly. Afterward they are annealed, the temperature being raised slowly, during 4 hr., to 1625 deg. fahr., kept at this temperature for 2½ hr., and then slowly cooled. The tensile strength of the metal is approximately 120,000 lb. per sq. in.

To produce these axle castings requires careful attention throughout the process. It necessitates special core and sand mixtures and careful workmanship in preparing the mold. The specifications for the castings call for the following limits:

Elements	Per Cent
Carbon	0.28 to 0.31
Manganese	0.60 to 0.75
Silicon	0.20 to 0.30
Nickel	1.00
Sulphur	0.05 maximum
Phosphorus	0.05 maximum

MATERIAL IN THE CHARGE

The charge for the furnace is made up of approximately 70 per cent purchased scrap of known analysis, consisting of punchings, plate, butt ends, I-beams, or solid-tire rims. The remainder is the returns, in the form of rejections, heads, gates and sculls or spills. About 100 lb. of metal from the previous heat is left in the furnace when the new charge is put into it. This forms a solid gummy mass and gives immediate electrical contact and a hot arc, eliminating the need of a starter such as coke. Care is exercised in charging, to prevent the necessity of much poking down as the melt progresses.

The preliminary melting is done on high tap. About one hour usually is required to melt down the charge. For preliminary determination of the carbon content, a sample is taken and a color test is run; but the reading of a fracture in highly refined steel is rather uncertain, and a small laboratory is recommended for testing the carbon by the color method.

Since low-carbon steels are used as a base, the melt usually will run low in carbon. The graphite electrodes, immersed in the charge, usually furnish the desired amount, but cast iron and pig iron can be added if needed. Should the test show a higher carbon-content than specified, a high-grade, clean, hard-hematite, low-phosphorus iron-ore is added to bring it down. The ore is added in small quantities until the specified carbon-content is reached. The bath is then brought to the pouring temperature, and tests are made of the metal and the slag to ascertain whether deoxidation has been thorough. This can be ascertained from the slag, a light-green color of the fracture indicating complete deoxidation. As a further precaution, we add to the ladle a small quantity of pure aluminum. The entire heat is tapped into a large ladle, the slag is skimmed off carefully, and a protective covering of clean silica sand is put on. The metal is then transferred to pouring ladles of about 100 lb. capacity.

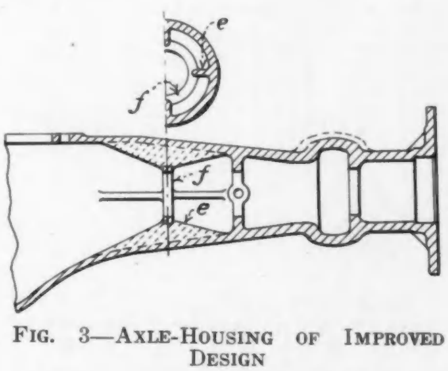


FIG. 3—AXLE-HOUSING OF IMPROVED DESIGN

CURRENT AND MATERIALS REQUIRED

To obtain satisfactory results, the material used must be very carefully selected. Limestone and fluorspar are kept on hand to dissolve the slag, when necessary, if alloys are to be added; afterward, silica sand is added to bring the slag to its normal consistency. Following are listed the current, time and electrodes required per ton to produce metal, in quantities of about 2800 to 3000 lb., from our smaller furnace:

Current, net	602 kw.
Graphite electrodes, net	8 lb.
Melting time	40 min.
Finishing time	18 min.

The average time per heat of 2800 lb. is 1 hr. 27 min. With the silica-brick roof, the average number of heats obtained was 96. With the vitrified-brick roof, 300 heats are expected before renewal.

In a book by Frank T. Sisco,[2] an excellent explanation of the chemistry of the acid processes is given.

Finish in Honed Cylinders

THE general conception is that a cylinder, to give the best results, must show a high finish, that is, a bright surface. That has been proved an error in the case of automobile cylinders. One manufacturer has stated that he is removing from 0.003 to 0.005 in. within 2 min., in honing his cylinders. After assembling and running the engine for 1 to 1½ hr., the cylinder is found to have a glass-like surface, equivalent to that obtained in the ordinary reamed cylinder after more than 1000 miles of running.

The little fuzz, if I may call it that, which seems to cut down the effect of the light, as compared with the ground cylinder, helps to remove the corresponding fuzz on the rings. We have not been able to find any marks that were 0.00025 in. deep, but they are just enough to remove the uneveness of the ground piston-rings, so as to give good service-conditions quickly. This same manufacturer said he had run one of his automobiles at 75 m.p.h. within 1½ hr. after being assembled. That indicates an almost perfect cylinder from the honing process. [From oral remarks by C. G. Williams, in presenting his paper on Honing at the Production Meeting. The paper was printed in THE JOURNAL for December, 1928, p. 561.]

[2] See The Manufacture of Electric Steel, p. 288, McGraw-Hill Book Co., 1924.

Standardization Activities

Conference on AN Standards

S.A.E. Specifications on Propeller-Hubs, Shaft-Ends and Rubber Grommets Adopted as AN Standards

THE AN Standards Conference held in Philadelphia at the Naval Aircraft Factory, Feb. 11 to 14, inclusive, brought together officials of the Air Corps of the Army and the Navy, as well as a large number of representatives of manufacturers supplying these services.

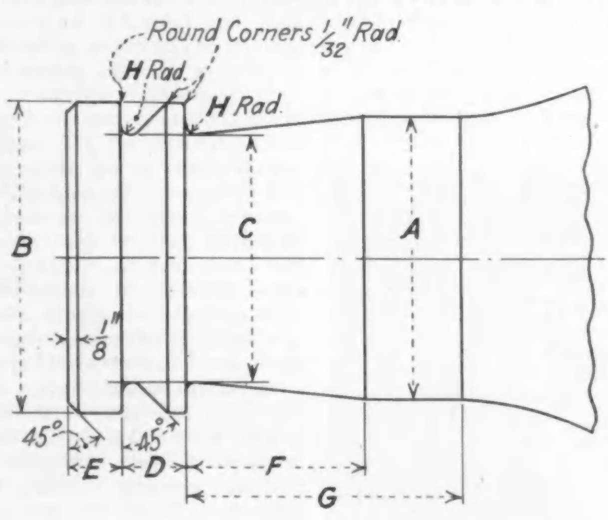
The conference this year was preceded by preliminary sessions that enabled the Army and the Navy to reconcile differences in the respective specifications under consideration.

The conference was divided into four groups: materials, powerplant, parts and instruments. At all of the sessions at which subjects of interest to the commercial-airplane manufacturer and user, or subjects contemplated or under consideration by the Aircraft or the Aircraft-Engine Division of the S.A.E. Standards Committee were discussed, the Society was represented by the chairmen or members of the subdivisions working on such subjects, and by a member of the Standards Department.

The S.A.E. Specifications for Splined Propeller-Hubs and Shaft-Ends, on which the S.A.E. Aeronautic Division has been working during the last year, were approved as AN Standards. In the formulation of these specifications, the Aeronautic Division had the cooperation of the Army and the Navy, as well as of the various engine manufacturers.

At one of the sessions devoted to the standardization of parts, the recently revised S.A.E. Specification on Rubber Grommets was approved as an AN Standard, as the grommets covered are applicable equally to airplane and to automobile use. The Specifications for Propeller-Blade Ends, Clamp Rings, and Clamp-Ring Bolts and Nuts, which have been approved as AN Standards, will be submitted to the S.A.E. Aircraft-Engine Division for approval as S.A.E. Specifications.

An outline of these specifications will be found in this issue of THE JOURNAL, under another heading in Standardization Activities.



Material-Aluminum Alloy

Blade End Number (Hp. Recommended)	A	B	C	D	E	F	G	H
00	$2.250^{+0.000}_{-0.003}$	$2.495^{+0.000}_{-0.003}$	2.000±0.010	$0.500^{+0.002}_{-0.000}$	0.4375±0.010	1.3125±0.010	2.1875±1/16	3/32
0	$3.000^{+0.000}_{-0.003}$	$3.250^{+0.000}_{-0.003}$	2.625±0.010	$0.6875^{+0.002}_{-0.000}$	0.562±0.010	1.6875±0.010	2.9375±1/16	1/8
1	$3.875^{+0.000}_{-0.003}$	$4.245^{+0.000}_{-0.003}$	3.375±0.010	$0.875^{+0.002}_{-0.000}$	0.750±0.010	2.375±0.010	3.750±1/16	5/32
1½	$4.1875^{+0.000}_{-0.003}$	$4.620^{+0.000}_{-0.003}$	3.6875±0.010	$1.0625^{+0.002}_{-0.000}$	0.875±0.010	2.6875±0.010	4.1875±1/16	5/32
2	$4.500^{+0.000}_{-0.003}$	$4.995^{+0.000}_{-0.003}$	3.875±0.010	$1.250^{+0.002}_{-0.000}$	1.000±0.010	3.125±0.010	4.625±1/16	5/32
3	$5.000^{+0.000}_{-0.003}$	$5.620^{+0.000}_{-0.003}$	4.3125±0.010	$1.375^{+0.002}_{-0.000}$	1.125±0.010	3.438±0.010	5.124±1/16	3/16

Propeller-Blade Ends and Clamp-Rings

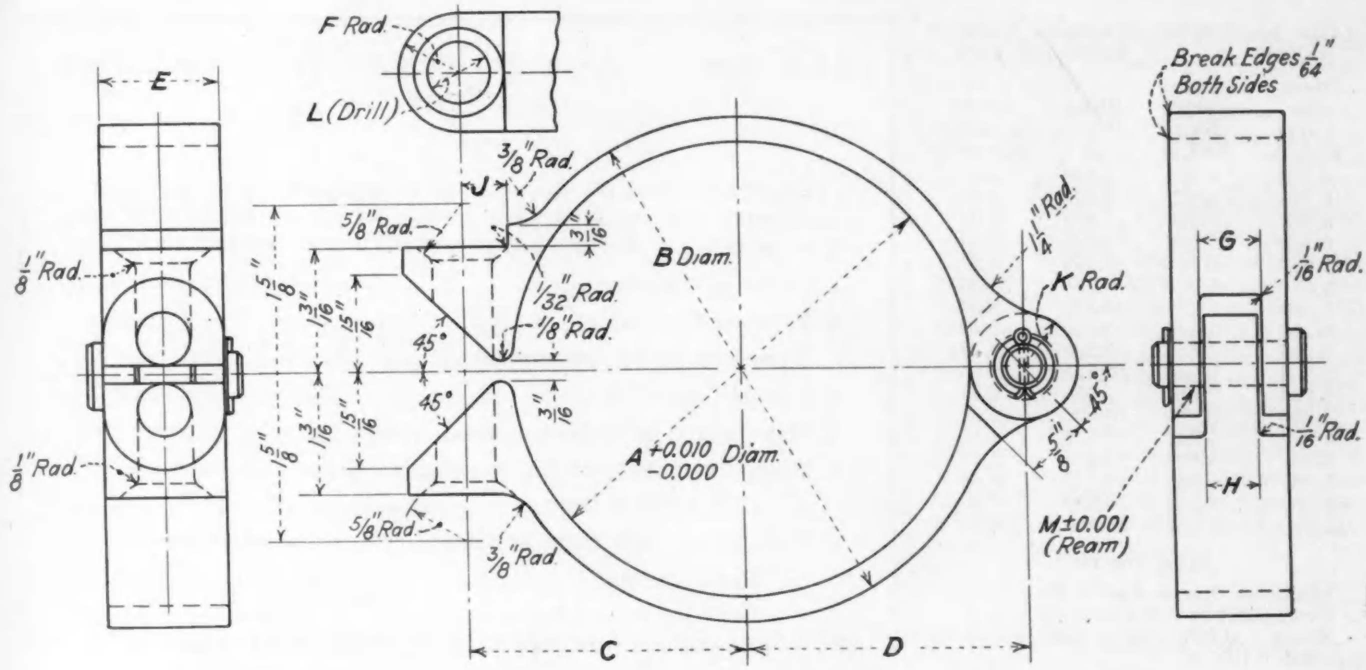
THE increasing use of metal propellers with detachable blades has given rise to standardization of the essential dimensions of the blade-end as attached to the propeller-hub. A table of dimensions has been approved by the AN Standards Conference as an AN Standard, and it has been suggested that, as detachable-blade propellers are used extensively on commercial aircraft, the Aircraft-Engine Division of the Standards Committee should approve and publish this standard as an S.A.E. Specification, for the benefit of commercial industry. The accompanying specification will therefore be submitted for approval to the Division at its next meeting.

Likewise, the Aircraft-Engine Division will be asked to consider the AN Standards for Clamp-Rings and Clamp-Ring Bolts and Nuts, which are used in attaching the blades to the hub. The proposed specifications are shown on pages 340 and 341.

Taper Standardization

ONE of the more important standardization projects that were taken up by the Sectional Committee on the Standardization of Small Tools and Machine-Tool Elements after its organization in 1922 was the development, if possible, of a standard series of tapers for use primarily in holding machine-tools. A preliminary study resulted in a long discussion of the project at a meeting of Technical Committee No. 3 of the Sectional Committee in Pittsburgh last May, and to the decision to continue research work relating to the holding power of various tapers for different classes of tools such as drills and milling-cutters.

At a meeting of the Technical Committee in New York on Dec. 5, 1928, that was well attended by machine-tool builders and users, it was decided



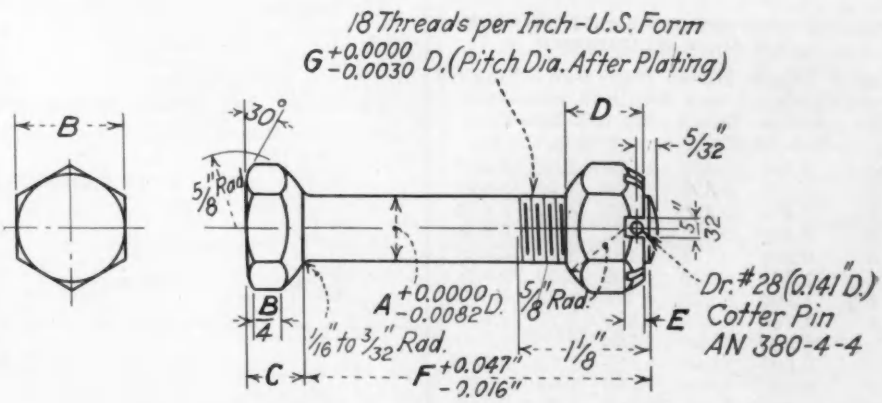
Material-Steel-2330, 6130 or 6135
Finish-Cadmium Plate
Heat Treat-Tensile Strength 125,000 lb. per sq. in.
Scleroscope Hardness 35-40

Size A	B	C	D	E	F	G	H	J	K	L	M
4 1/4	4 11/16	2 9/16	2 5/8	1 1/8	9/16	9/16	17/32	7/16	1/2	19/32	0.438
4 3/8	4 13/16	2 5/8	2 11/16	1 1/8	9/16	9/16	17/32	7/16	1/2	19/32	0.438
4 5/8	5 1/16	2 3/4	2 7/8	1 3/16	19/32	19/32	9/16	15/32	9/16	21/32	0.500
5	5 1/2	3	3 1/16	1 1/4	5/8	5/8	19/32	15/32	9/16	21/32	0.500

that for the present the Technical Committee would recognize, first, a system of tapers with 0.750-in. slope as shown in Table 1 and, second, a composite system of tapers based on the Morse and the 0.750-in. series as shown in Table 2.

Proposed Standard Machine Tapers

With reference to the tapers in Table 1, the 0.250, 0.375 and the 1.50-in. diameters were incorporated because it was the consensus of opinion of those taking an active part in this program that two sizes smaller than the Morse No. 1 and an intermediate size between the Morse Nos. 4 and 5 tapers should be added. The formula for the plug depth that is proposed, after having given careful consideration to the diameters and lengths of the present Morse tapers, will permit the proposed standard to be consistently expanded to meet possible future requirements. Although the Technical Committee feels that this tentative recommendation will provide a suitable series of tapers of 0.750 in. per ft., it should not be construed as representing a series of tapers suitable for adoption for machine-tool spindles.



Bolts-Steel 2330, 6130 or 6135
Nuts-Steel-1025
Scleroscope Hardness for Bolts 35-40
Heat Treat Bolts-Tensile Strength 125,000 lb. per sq. in.
Finish-Cadmium Plate

Size	A	B	C	D	E	F	G	Clamp Ring
9/16-18	0.5625	7/8	15/32	21/32	3/16	2 7/8	0.5264	4 1/4-4 3/8
5/8-18	0.6250	15/16	33/64	49/64	1/4	3	0.5889	4 5/8-5

TABLE 1—PROPOSED STANDARD MACHINE TAPERS—0.750-IN. TAPER PER FOOT

Diameter, Large End, In.	Diameter, Small End, In.	Plug Depth, In.	Ratio, Length to Diameter
0.250	0.188	1.000	4.00
0.375	0.281	1.500	4.00
0.500	0.375	2.000	4.00
0.750	0.586	2.625	3.50
1.000	0.797	3.250	3.25
1.250	1.016	3.750	3.00
1.500	1.227	4.375	2.92
1.750	1.445	4.875	2.79
2.000	1.656	5.500	2.75
2.500	2.086	6.625	2.65
3.000	2.516	7.750	2.58
4.000	3.375	10.000	2.50
5.000	4.242	12.125	2.43
6.000	5.102	14.375	2.40
8.000	6.820	18.875	2.36
10.000	8.547	23.250	2.33
12.000	10.273	27.625	2.30

PLUG DEPTH

Diameter, Large End $= D$
From 0.250 to 0.500 in. $= 4D$
Above 0.500 in. $= 2.2D + \sqrt[10]{D}$ to nearest 0.125 in.

PROPOSED COMPOSITE MACHINE TAPERS

Throughout the course of the Committee's study of taper standardization there have been varying opinions as to whether there should be more than one series of tapers and also what the tapers in such a series should be. One suggestion that has met with general favor is to develop a series to consist of tapers that already are in wide use for the range of sizes to which each applies best. The proposed

TABLE 2—PROPOSED COMPOSITE STANDARD FOR MACHINE TAPERS

Taper No.	Diameter Large End, In.	Diameter Small End, In.	Plug Depth In.	Ratio Length to Diameter,	Taper per Foot In.
00	0.250	0.200	1.000	4.00	0.600
0	0.375	0.300	1.500	4.00	0.600
1	0.475	0.369	2.125	4.47	0.600
2	0.700	0.572	2.562	3.66	0.602
3	0.938	0.778	3.187	3.40	0.602
4	1.231	1.020	4.062	3.30	0.623
4½	1.500	1.273	4.375	2.92	0.623
5	1.748	1.475	5.187	2.97	0.630
	2.000	1.656	5.500	2.75	0.750
	2.500	2.086	6.625	2.65	0.750
	3.000	2.516	7.750	2.58	0.750
	4.000	3.375	10.000	2.50	0.750
	5.000	4.242	12.125	2.43	0.750
	6.000	5.102	14.375	2.40	0.750
	8.000	6.820	18.875	2.36	0.750
	10.000	8.547	23.250	2.33	0.750
	12.000	10.273	27.625	2.30	0.750

NOTE—Numbers 1, 2, 3, 4 and 5 are present Morse tapers.

PLUG DEPTH

Diameter, Large End $= D$
From 0.250 to 0.375 in. $= 4D$
0.475, 0.700, 0.938, 1.231 and 1.748 in. = Present Morse Standard
1.500 and above 1.748 in. $= 2.2D$ plus $\sqrt[10]{D}$ to nearest 0.125 in.

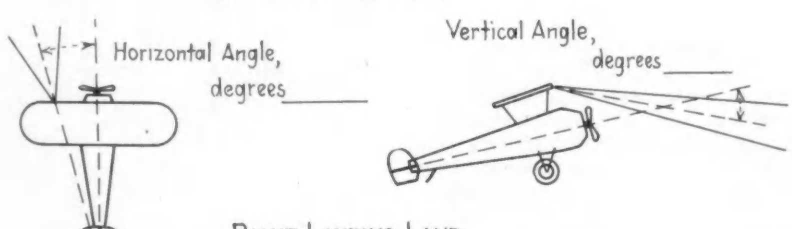
S.A.E. AIRCRAFT-LIGHTING COMMITTEE INSTALLATION DATA SHEET—A

TEST NO. ......

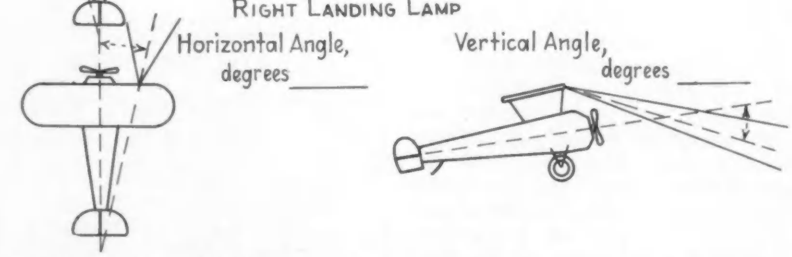
(Use a new sheet for each change of equipment or adjustment of equipment; also use same test number as above for all pilot daily report sheets on this particular installation of equipment).

1. Name of company ....
2. Type and model of plane ....
3. Type and model of engine ....
4. Ground angle of plane ....
5. Make and type of landing-lamp used ....
6. Where mounted—Right landing-lamp ....
   Left landing-lamp ....
7. Distance of each from horizontal center-line of plane—
   Right lamp ....
   Left lamp ....
8. Which lamp can be aimed from the cockpit by the pilot? ....
9. Through what vertical angle can the movable lamp be operated?
   ....
10. Kind of bulb used—volts ....
    Amperes ....
    Watts ....
11. Make and type of battery used ....
12. Voltage at landing-lamp sockets.
    a. Left socket, all lamps burning ....
    b. Left socket, all lamps off ....
    a. Right socket, all lamps burning ....
    b. Right socket, all lamps off ....
13. Degree spread of lens used on each landing-lamp—
    Right ....
    Left ....
14. How were beams aimed with respect to longitudinal center-line of ship?

LEFT LANDING LAMP



RIGHT LANDING LAMP



15. Date of installation ....
    Installation checked by ....

S.A.E. AIRCRAFT-LIGHTING COMMITTEE
PILOT'S DAILY REPORT SHEET—B

TEST NO. ....

1. Trip from .... to ....
2. Time left .... Arrived ....
3. Atmospheric conditions ....
4. Specific gravity of battery—Start........... Finish ....
5. How long was right landing-lamp used? ....
6. How long was left landing-lamp used? ....
7. How long were both used at the same time? ....
8. For what purpose were they used? ....
9. Was the movable landing-lamp useful? ....
   For what purpose? ....
10. Was the right landing-lamp aimed correctly? ....
    Vertically ....
    Horizontally ....
    Was the horizontal spread of beam great enough? ....
    Was the vertical spread of beam great enough? ....
    Was the light bright enough? ....
11. Was the left landing-lamp aimed correctly? ....
    Vertically ....
    Horizontally ....
    Was the horizontal spread of beam great enough? ....
    Was the vertical spread of beam great enough? ....
    Was the light bright enough? ....
12. Describe briefly any trouble with the lighting equipment.
    ....
    ....
    ....
13. Suggestions for improvement ....
    ....
    ....
    ....

Signature of Pilot ....
Name of Company ....
Date ....

composite series of machine tapers given in Table 2 consists of the smallest two sizes having a 0.600-in. taper per ft., the Morse sizes Nos. 1 to 5 inclusive, with an intermediate No. 4½ size, and a large range having diameters on the large end extending from 2 to 12 in. and having a taper of 0.750 in. per ft.

These proposals are submitted by the Committee to users for their comment before further action is taken toward final approval of a definite recommendation. Members of the Society are especially urged to review this tentative report and submit any constructive criticisms thereof, together with their opinion as to what series of tapers is preferable, so that such comments and suggestions can be forwarded to the Committee before its next meeting.

Subsequent Procedure on Recommendations

Technical Committee No. 3 of the Sectional Committee consists of representatives of the National Machine Tool Builders Association, American Society of Mechanical Engineers, and Drill and Reamers Society, a Navy Department representative, two representatives of the S.A.E., two representatives of the general Sectional Committee, and nine members-at-large representing different classes of industrial interests.

When Technical Committee No. 3 has completed its recommendation on a proposed standard for machine tapers, the report will be submitted to the general Sectional Committee for its approval, following which it will be successively referred to the sponsors for confirmation and to the American Standards Association for final adoption in conformity with committee organization and procedure, the Sectional Committee and the sponsors being responsible for the technical features of the report. The sponsors for this and other machine-tool standardization projects are the American Society of Mechanical Engineers, the National Machine Tool Builders Association, and the S.A.E.

Aircraft-Lighting Committee Progress

THE Aircraft-Lighting Committee, which is making a study of landing-light conditions and requirements, has recently been asked to approve the forms for recording data which were drafted by a Subcommittee appointed for the purpose. As previously announced, identical lighting-equipment will be installed on six airplanes operated by different companies. Some idea of the scope of the work undertaken may be obtained from the preliminary forms reproduced herein.

The information with reference to the types and makes of plane to be used in these tests has been obtained from the Stout Metal-Airplane Division of the Ford Motor Co., Pitcairn Aviation, Inc., Boeing Air Transport, National Air Transport, the Army Air Corps, and the Guggenheim Fund for Aeronautics, which are the cooperating organizations. The equipment has been assembled by the Committee preparatory to installation.

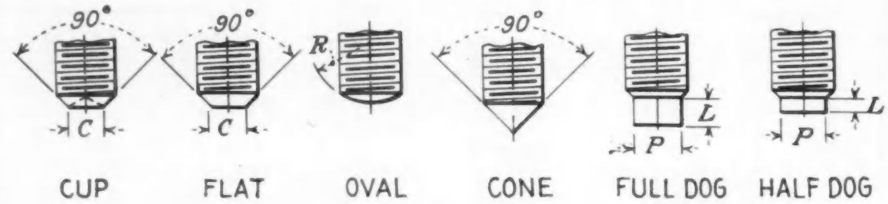
Socket-Head Cap-Screws

FOR several years the Sectional Committee on Bolt, Nut and Rivet Proportions, organized under American Standards Association procedure by the S. A. E. and the American Society of Mechanical Engineers as sponsors, has been developing specifications for various types of screw and bolt. It is now proposed that a similar standard for socket-head cap-screws be formulated and adopted through the Sectional Committee.

The accompanying tables, which have been approved by a number of the screw manufacturers, constitute the tentatively proposed standard submitted herewith for review, especially by

the users in the automotive industry of this class of screws and by screw manufacturers who have not had an opportunity to review the proposal. The principal parts of the specifications to be considered are the head dimensions and the number of styles of screw points. The six screw points shown are believed by the manufacturers who have already indicated their approval to be the minimum number that should to be given in the standard.

Members of the Society are especially requested to review the tentative proposal and to send to the Standards Department at the Society headquarters any constructive criticisms or suggestions they may desire to offer. As in the case of the reports of other Sectional Committees for which the Society is a sponsor, this report when finally passed by the Sectional Committee will be submitted to the Society for approval, following which the proposal will be passed by the American Standards Association with regard to committee organization and procedure.

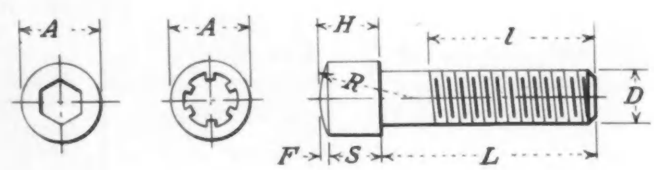


SET-SCREW POINTS OF SOCKET-HEAD CAP-SCREWS

D Screw Diameter	*C* Cup and Flat Max.	Min.	*R* Oval	*P* Full and Half Dog Max.	Min.	*L* Full Dog	Half Dog
1/4	0.130	0.120	1/4	0.163	0.153	1/8	1/16
5/16	0.169	0.159	5/16	0.212	0.202	5/32	5/64
3/8	0.206	0.196	3/8	0.260	0.250	3/16	3/32
7/16	0.242	0.232	7/16	0.305	0.295	7/32	7/64
1/2	0.281	0.271	1/2	0.355	0.345	1/4	1/8
9/16	0.319	0.309	9/16	0.403	0.393	9/32	9/64
5/8	0.356	0.346	5/8	0.451	0.441	5/16	5/32
3/4	0.435	0.425	3/4	0.552	0.542	3/8	3/16
7/8	0.513	0.503	7/8	0.651	0.641	7/16	7/32
1	0.589	0.579	1	0.747	0.737	1/2	1/4
1 1/8	0.660	0.650	1 1/8	0.838	0.828	9/16	9/32
1 1/4	0.748	0.738	1 1/4	0.950	0.940	5/8	5/16
1 3/8	0.814	0.804	1 3/8	1.030	1.020	11/16	11/32
1 1/2	0.901	0.891	1 1/2	1.145	1.135	3/4	3/8

FORMULAS

Screw Diameter D
  Nominal—No Formula
Cup and Flat Point C
  Maximum $= 0.7$ in. $\times$ Minimum Minor Diameter — N. C. 2
  Minimum $=$ Maximum $- 0.010$ in.
Radius of Point R
  $R = D$
Diameter of Dog Points P
  Maximum $= 0.9$ in. $\times$ Minimum Minor Diameter N. C. 2
  Minimum $=$ Maximum $- 0.010$ in.
Length of Full and Half Dog Points L
  For Full Dog $L = 1/2D$
  For Half Dog $L = 1/4D$
Included Angle of Cone
  Points $= 90$ deg. for all diameters



HEAD DIMENSIONS OF SOCKET-HEAD CAP-SCREWS

Nominal Size, In.	*D* Maximum Screw Diameter	*A* Head Diameter, In. Max.	Min.	*S* Side of Head, In. Max.	Min.	*R* Radius of Chamfer, In.	*F* Height of Chamfer, In. Max.	Min.	*H* Height of Head, In Max.	Min.
1/4	0.250	0.375	0.364	0.230	0.216	3/4	0.024	0.020	0.250	0.240
5/16	0.3125	0.437	0.424	0.2895	0.275	15/16	0.027	0.023	0.3125	0.3025
3/8	0.375	0.562	0.547	0.343	0.329	1 1/8	0.036	0.032	0.375	0.365
7/16	0.4375	0.625	0.608	0.4035	0.3895	1 5/16	0.038	0.034	0.4375	0.4275
1/2	0.500	0.750	0.731	0.456	0.442	1 1/2	0.048	0.044	0.500	0.490
9/16	0.5625	0.812	0.792	0.5175	0.5035	1 11/16	0.049	0.045	0.5625	0.5525
5/8	0.625	0.875	0.853	0.577	0.563	1 7/8	0.052	0.048	0.625	0.615
3/4	0.750	1.000	0.976	0.698	0.684	2 1/4	0.056	0.052	0.750	0.740
7/8	0.875	1.125	1.098	0.820	0.806	2 5/8	0.059	0.055	0.875	0.865
1	1.000	1.312	1.282	0.934	0.920	3	0.070	0.066	1.000	0.990

FORMULAS

Head Diameter A
  Maximum $A =$ Nominal
  Minimum $A =$ Maximum $A - (0.020$ Maximum A $+ 0.004$ in.)
Side of Head S
  Maximum $S =$ Maximum $H -$ Minimum F
  Minimum $S =$ Minimum $H -$ Maximum F

Radius of Chamfer $R - 3D$
Height of Chamfer F
  Maximum $F =$ Nominal
  Minimum $F =$ Maximum $F - 0.004$ in.
Height of Head H
  Maximum $H = D$
  Minimum $H = D - 0.010$ in.

The Traffic Problem in Paris

THE problem of traffic control in Paris has been attacked in a thorough and statesmanlike way. On March 15, 1925, a general ordinance was issued which codified the large number of orders, respecting the conduct of traffic, promulgated over many years by succeeding prefects of police. A most important document this, for it comprises no fewer than 296 articles and governs every conceivable situation.

There is a theoretical limit of 50 km. (31 miles) per hour in the center of the city, but this speed naturally cannot be attained in periods of congestion, and at other hours it is winked at. Vehicles may not turn in a street by reversing. Deliberate attempts, with successful results, have been made to exclude slow-moving vehicles from the main thoroughfares.

The ordinance forbids, between the hours of 3 and 7 p. m., the use of a large number of streets by such vehicles as are unable to keep pace with the general stream; also the parking of vehicles on both sides of the public way whenever the space between them is insufficient for two lines of traffic. In such streets the vehicles are compelled to draw up at the curb on the side of the even numbers on the even dates of the month, and on the side of the odd numbers on the odd days. The authorities have been considering the possibility of providing large underground garages at key points connected with street subways; the problem at present is mainly a financial one.

Rights of Pedestrians

The French highway code recognizes the right of a pedestrian to be warned of the approach of a vehicle, but, on the other hand, it imposes upon him the duty of promptly responding to that warning. The Paris municipality has done everything in its power to facilitate the crossing of the carriageway by pedestrians. It has multiplied the refuges; it has opened subterranean passages and plans the making of new ones, but the pedestrian has not been cured, and it is difficult to discipline him. However, at certain busy traffic-points crossways for pedestrians are indicated by double lines of steel studs. These crossways are invariably found at the signaled intersections; and similar restrictions exist, and are rigidly enforced, at all police-regulated intersections.

In their use of electric day-color-light signals for road traffic, the French have not been able to economize in policemen controllers. At the Place de l'Opera, for instance, eight gendarmes are continuously employed throughout the day. Likewise, despite the use of traffic signals at the junction of the Boulevards Haussman, des Italiens and Montmartre, four policemen are regularly in attendance, while three are found necessary at neighboring cross-roads.

Traffic Control

The signals in use are of two kinds: one, for traffic control, capable of showing a red light as a "stop" indication, and the other, used at the entrance to one-way streets, showing red by intermittent flashes. The latter, which provides a very effective indication, is displayed above the words "Sens Interdit" (passage forbidden), the light being placed about 10 ft. 6 in. above the ground. It is furnished with a 100-watt gas-filled electric lamp.

Each set of cross-road signals is hand-operated from a control box, which is slung on one of the lampposts. The equipment comprises four beacons, except where one of the cross-roads is a one-way street, when only three are used, entrance to the one-way thoroughfare being prevented by a "Sens Interdit" flashing-signal. An exception is provided by the Place de l'Opera, where the layout demands the use of no fewer than seven signals.

A few seconds before the red aspect is extinguished, thus indicating permission to proceed, an electric bell rings. This serves as a warning for the "right-away" signal and encourages every driver to be on the alert for the disappearance of the red. The result is that all the vehicles start off promptly. Each signal is placed 12 ft. 6 in. above the carriageway, and is illuminated by an incandescent lamp of 300 cp. It measures 1 ft. 4 in. in diameter, and visibility during the day is increased by the use of a cowl 9½ in. in length. Behind the beacon is situated a second and smaller reflector, 4 in. in diameter and equipped with a 100-cp. lamp, which serves as a guide to police and pedestrians. It has been found unnecessary in the Paris system to employ a green aspect also, the disappearance of the red light being sufficient indication of the permission to proceed.—*Modern Transport.*

Pan-American Highway Realizable

IN informed circles the scheme of a continuous highway linking the nations of North, Central, and South America no longer is considered an ephemeral dream, according to testimony at the hearing before the House Committee on Foreign Affairs, when the resolution was up for consideration. With the advance of the science of road-building, no obstacles greater than those already overcome in building existing links of the highway, it was testified, bar the way to the realization of the task.

Wilbur J. Carr, Assistant Secretary of State; Dr. L. S. Rowe, Director General of the Pan-American Union; Thomas H. MacDonald, Chief of the United States Bureau of Public Roads; and Pyke Johnson, Executive Director of the Pan-American Confederation for Highway Education, appeared before the committee in support of the measure.

After quoting from the last message of the President to Congress, Representative Cole of Iowa recited that the Havana Conference had requested the Pan-American Union to undertake the study, and the recent action of the Union in transferring the project to the Pan-American Confederation for Highway Education, which has branches in ten of the Latin American countries and in the United States.

"In Latin America," said Mr. Cole, "nothing at present is more talked of than road building and the connecting up of roads already built or under construction into the ultimate longitudinal continental highway. On his recent 'good-will tour' President-elect Hoover made frequent references to this great Pan-American project, and everywhere it met with the most enthusiastic support.

"So far as the United States is concerned, the building of no special highway to connect with the Mexican highway south of Laredo, Texas, is contemplated. This Country is already covered with a network of hard-surfaced roads, all of which will or can be connected with roads leading to the Mexican frontier. The same is true of Canada, which is also contemplated to be made a part of this project."

News of Section Meetings

(*Continued from p.* 263)

for passengers, on the basis of reasonably standardized dimensions. Comfort, he stated, is dependent primarily, not on overstuffed upholstery, but on a seat design allowing the relaxed posture of the human body to be maintained without fatigue.

Speaking of the 1929 National Automobile Shows, Mr. Mercer commented upon the light-looking upper structure of most cars, and the large windows which render an automobile body attractive. Apparently the trend is toward a body designed, not simply as a superstructure for the chassis, but as an enclosure for the whole, fabricated from metal that gives it strength, yet results in parts that are nearly insensible as to size, particularly of the upper body and the door pillars. In fact, Mr. Mercer believes that the future body will embrace all present extraneous and projecting parts, such as lamps and fenders.

In the discussion, E. W. Weaver, of the Trundle Engineering Co., asked regarding the tendency toward adjustable seats. Mr. Mercer thought that, while cars are made for the average person, they must be built so as readily to accommodate persons either below or above average height; this holds particularly true in the case of the driver's seat.

Coach-Body Weight and Strength

A question of proper weight for de luxe motorcoaches was raised, and Peter Licursie, of the Lang Body Co., stated that the weight of such vehicles, completely equipped, usually runs from 15,000 to 18,000 lb., with the chassis accounting for 9500 to 9700 lb. or even a little more, leaving it to the body builder to keep the weight of the body down as much as possible. P. W. Steinbeck, of the Bender Body Co., mentioned the use by his company of fir and other light woods in place of ash, in an endeavor to reduce the body weight, particularly for motorcoaches to be used in the South. He also referred to a 27-passenger coach, built by the Aluminum Co. of America, which saved 1200 to 1400 lb. of weight, although it was exceedingly expensive. Charles Roessler, of the Lang Body Co., claimed that the use of steel makes possible substantial savings in body weight and stated that his company is now building a 39-passenger all-steel body that weighs little more than a wood body of the same capacity.

Secretary Blair, after speaking of the improvements in spring design aimed at reducing sidesway, asked Mr. Mercer regarding the strength of motorcoach bodies to withstand side-blows in accidents, particularly when turning over. Mr. Mercer agreed that some steel bodies, being merely shells with very little reinforcement, are crushed under such circumstances, and added that, while he considers this a very important matter, he knows of nothing in particular that is being done in body construction to overcome this difficulty.

Other Body Questions Considered

Discussion then turned to the relative permanence of performance-quality of the chassis parts as contrasted with that of the bodies. L. L. Williams compared the durability of Pullman railroad-cars with that of present-day de luxe motorcoach bodies; and G. W. Smith, Jr., of the White Motor Co., stated that, whereas the weight of a Pullman car is approximately 1700 lb. per passenger seat, motorcoach manufacturers have mostly tried to keep this factor down to 350 lb.

Replying to several questions addressed to him, Mr. Mercer stated that body noises have been reduced on some experimental jobs, where manufacturers coated either the frame and panels, or only the outside fringe of the panel, with a gummy material which acts as a silencer as long as it remains plastic. He said that some body builders consider felt superior to rubber or other materials for packing, at least until it becomes wet and hard. Proper fender clearance, he remarked, is essential if rumbles are to be minimized, but as a rule body builders are obliged to follow specifications in building their product. Fabric bodies, he added, are remarkably silent and durable, yet for some reason have proved "hard to sell the public." It is feasible to use them for high-speed interurban motorcoaches and thereby save one-third in weight compared with steel bodies. However, fabric bodies present the problem of a durable color-scheme, since different ingredients have to be used on fabric and metal surfaces to build up the same color, and the difference in base color will be revealed in course of time because of surface wear.

Attention was called by F. C. Stier to the scarcity throughout the Country of really qualified body service men, and M. Bleiweiss, of the Economy Buick Co., stated that his firm lately had come to realize that such service is necessary and is now taking steps to give it.

Regarding ventilation of motorcoaches and taxicabs, Mr. Mercer stated that this apparently has not received the attention it deserves, particularly in matters of experiments and tests. Mr. Weaver cited a case of a Pullman-car floor-covering having been adopted successfully by extensive operators of motorcoaches.

According to Mr. Mercer, one of the principal reasons why bodies are not as silent as the public might desire is that vehicle manufacturers are not prepared to pay a sufficient price for body quality. He restated his opinion that the all-steel body, without joints, will be the only solution of the problem of most body troubles, and said that he knows from personal experience that some of these bodies which have been in use for a time have fewer squeaks and troubles than when they were new.

Large-Bore versus Small-Bore Engines

THE slogan "a product easy to build good" best applies to the large-bore short-stroke engine, as compared with the small-bore long-stroke engine, according to Alex Taub, who delivered his paper on the Desirability of a Large-Bore Engine at the meeting of the Milwaukee Section held Feb. 6 at the Milwaukee Athletic Club. The dinner was attended by 72 members and guests, and 94 were present at the technical session. Vice-Chairman Arthur C. Wollensak presided in the absence of Chairman Cyrus L. Cole.

A Nominating Committee for officers of the Section to be elected for the ensuing year was elected as follows: Joseph B. Armitage, Arthur W. Pope, Jr., Louis F. Reinhard, Fred M. Young and George C. Appel. Very interesting motion pictures were shown, entitled Commander Byrd at the North Pole. Mr. Taub's paper, previously presented at the Annual Meeting at Detroit, is published in this issue, together with the discussion which followed its presentation, beginning on p. 292.

Discussion at Milwaukee

In answer to a question as to the relative costs of the large-bore and the small-bore engine, Mr. Taub said that if, for instance, a low-price engine is to be built and every imaginable advantage is to be utilized, it is possible to build a small-bore engine to sell at the same price as a large-bore engine; but that in so doing there will be less utility per dollar because the products will not be comparable, that is, the large-bore engine will be more durable than will that type of small-bore engine. But if a small-bore

engine is built so that everything possible is done to make it a satisfactory engine, the costs will be from 15 to 18 per cent higher.

Asked to discuss the size limits to which the large-bore short-stroke engine can be carried to advantage, Mr. Taub stated that engines of the following sizes had proved progressively satisfactory as the bore was increased: 3 1/8 x 3 3/8 in., 3 3/16 x 3 5/8 in., and 3 5/16 x 3 3/4 in., the last size being described as a happy combination of bore and stroke dimensions.

It was stated by J. B. Fisher, of the Waukesha Motor Co., that his company has not observed it to be any easier to control leakage past the piston-rings on the large-bore engines than it is to control it on small-bore jobs. He said that just about as great a problem regarding the piston-rings is presented by the company's 6 3/4-in.-bore engines as by those of small bore. In his opinion, one problem that demands the immediate attention of engineers is that of securing a better piston and piston-ring assemblage.

How to Control Combustion

Experts at Detroit Section Meeting to Discuss the Subject of Robert Janeway's Paper

RETURNING to normalcy after the three leading Automobile Shows of the year, the **Detroit Section met at** the Book-Cadillac Hotel on Feb. 11, with the customary dinner. A large number of members and guests showed their interest in the Section's most strictly technical session of the year by their discussion of the paper on Combustion Control, by Robert N. Janeway, a consulting engineer who has specialized in combustion-chamber design.

After a brief tribute to the memory of Edwin Denby, Chairman B. J. Lemon congratulated the Section on the attendance at the first six meetings of the season. The total attendance at the six dinners was 2937 and at the meetings 3473, increases of approximately 81 and 45 per cent, respectively, over the attendance last year. He also said that the total active membership of the Section has now reached 1000 for the first time since section associate membership was discontinued.

Chairman Lemon called attention to the "ladies' night" meeting on Feb. 25, the announcement of which sounds like a repetition of the similar occasion last year, with W. B. Stout as the chief speaker and the High-Hats to furnish music for dancing after 10 o'clock. Another body meeting is scheduled for March 25, with E. E. Chamberlain, sales manager of the Packard Motor Car Co., as speaker; and an aeronautic meeting will be held May 13, during the National Aeronautic Show in Detroit. Announcement was made of the appointment of Phillip J. Kent, of Chrysler Motors, to serve as secretary of the Section in place of Leon Chaminade, who has been transferred to South Bend, Ind.

Guests at the speakers' table, introduced by Chairman Lemon, included W. R. Strickland, President of the Society; Thomas Midgley, Jr.; and Professors G. B. Upton and A. C. Davis, of Cornell University. In introducing the subject of the evening, the Chairman remarked on the great development of experimental laboratories in connection with industry, particularly

ROBERT N. JANEWAY

the automotive industry, until they promise to outstrip the research work in universities.

OFFSET-CYLINDER-HEAD TECHNIQUE

In his paper Mr. Janeway first mentioned fuel dope and combustion-chamber design as the chief means of controlling combustion. His paper is devoted to the design question, which was given great impetus by Ricardo. The extensive spread of the application of the offset cylinder-head has been empirical, without understanding of the fundamental factors involved, and this paper is an attempt to establish a rational basis and to show the logical development of combustion control.

Internal-combustion engines cannot realize their theoretical efficiency because of variation in the specific heat, which in theoretical studies is usually considered constant. Turbulence is credited with being a help in eliminating detonation. The author considers this to be a function of the intake velocity rather than of combustion-chamber design, and holds that the form of the combustion-chamber has greatest effect at full throttle and high speed. Its effectiveness is due to its influence in cooling the unburned portion of the gas during the combustion period, and that is influenced by the location of the spark-plug. The best effect is found when the last of the mixture to be burned is contained in the thin space between the piston and cylinder-head that is secured in the offset-cylinder-head design.

Since the piston forms one side of this space, piston cooling has a very great effect on detonation. While the exhaust valve is often the hottest part of the combustion-chamber, its effect on detonation can be overcome by correct location of the spark-plug so that unburned gases will not pass over the valve during combustion.

The pressure-time characteristics of combustion are said to control detonation. Each case calls for an independent application of the fundamental principles. To obtain smoothness without loss of power, the volume of charge must be so distributed with respect to the spark-plug position as to obtain as nearly as possible uniform acceleration in the rate of pressure rise up to the maximum rate, without excessive increase in the explosion time, according to Mr. Janeway.

EXPERIENCES OF VARIOUS ENGINEERS

After the reading of the paper, Professor Upton was called upon to lead the discussion. In fact, the whole gathering had taken on the tone of a college reunion when Chairman Lemon recalled his relationship with Mr. Midgley, Professor Davis and Professor Upton at Cornell. Professor Upton explained his choice by the fact that it would avoid any possible hard feelings against a member of the Section after the "fight" was over.

R. V. Hutchinson, of the Olds Motor Works, said that his company has made engines with offset combustion-chambers for several years and has been unable to improve the design by mathematical analysis. He has observed the roughness of the engine to vary at different speeds. Arthur W. Pope, Jr., of the Waukesha Motor Co., remarked on the variation in possible compression in engines of different size, and affirmed that the shape of the combustion-cham-

ber determines the degree of turbulence.

Control of detonation in overhead-valve engines, according to Alexander Taub, of the Chevrolet Motor Co., has been secured in much the same way as in an L-head chamber. With no room to extend transversely, the chamber is folded up on itself.

In replying to these and other remarks, Mr. Janeway said that, if an engine is especially rough at some speed, the roughness probably is due to a critical speed rather than to explosion roughness. He said that a certain degree of freedom from the effect of cylinder size can be secured by correct design of the combustion-chamber. Compression pressure can be greater with supercharging because the initial temperature is not so high as when the same pressure is secured by compression in the cylinder. This condition is related to the observed fact that a considerable amount of throttling is required to stop the knock in an engine that is knocking badly; a change in pressure has little effect if the temperature change is not proportional. ROBERT N. JANEWAY.

New Car Features Reviewed

Engineers Tell Chicago Section Members of Improvements in Several Makes of 1929 Automobiles

ENGINEERING tendencies as expressed in present-day passenger cars were considered at the Automobile-Show Meeting of the Chicago Section, held on Jan. 29 at the Hotel Stevens. Vice-Chairman D. P. Barnard, 4th, addressing the 129 members present, announced that a number of prominent engineers would speak on the subject of engineering changes and improvements in 1929 passenger-car models built by their respective companies.

As first of the speakers, Edwin L. Allen, of the Auburn Automobile Co., read a paper by H. C. Snow, who was prevented from attending in person. The paper reviewed the principal features of this season's Auburn cars, in which the frame has been considerably stiffened to protect the body from excessive weaving. Other important changes include the mounting of the radiator on its base instead of on the sides and setting it directly on the front cross-member. A flexible cross-bar is riveted to the bottom center of the radiator, with arms extending out to either side and bolted to the front cross-member. This method of mounting, wrote Mr. Snow, allows the radiator to hinge at the bottom and, with the tie-rods at the radiator-top connecting diagonally to the body, permits a flexing between the frame and radiator without transmitting the flexing of the frame to the radiator.

Among other changes mentioned were the substitution of four-ring for three-ring pistons and the use of steel connecting-rods in place of the duralumin rods formerly used, which results in a closer bearing fit.

Cadillac and LaSalle Improvements

The next speaker, F. C. Hecox, of the Cadillac Motor Car Co., described the many improvements recently incorporated in his company's product. Cadillac and LaSalle cars are made with cast-iron pistons of a very low distortion-factor, which makes relatively close fitting possible. Distortion of piston-head and skirt is taken care of by a strut from the internal portion of the piston-head to the piston-boss. This design, it was explained, allows the use of a pressed fit on the piston-boss side where the locking screw fastens the wristpin in place, a slip-fit being used on the opposite boss of the piston. Wristpins are now pressure-lubricated through the connecting-rods, the design of which has been changed so that the rods are drilled on the side rather than in the center. An improved rubber mounting and steel spool have been adopted for the rear mounting of the engine, and the clutch throw-out lever is now of the ball-and-socket type, eliminating the use of shaft and yoke.

The syncro-mesh transmission, said Mr. Hecox, ranks among the principal improvements introduced by the Cadillac company this year. Its construction provides easy and noiseless shifting to and from second and third speeds. The gearset is of conventional design except for the syncro-mesh feature, which involves the use of bronze and steel cone-clutch devices together with actuating mechanisms for the same. In shifting, the speed of the gears is modulated by the hydraulic action of two dash-pots at the upper end of the yoke, one of which is designed to catch the movement of the second gear and the other that of the high gear. Operation of the dash-pots tends to slow down the movement of parts during the shifting period and provides a cushioning effect while proper synchronization of the rotating parts is taking place. Nevertheless, shifting-time is reduced, because it is no longer necessary to hesitate in neutral position for a time to avoid clashing.

Improvements in the brake system, which utilizes 16 sets of roller bearings in the brake-control mechanism, include a heat dissipator in the form of a coil spring having its ends swaged together around the external surface of all four brake-drums. This arrangement tends not only to dissipate the heat but to muffle possible brake noises.

Strength and rigidity of the chassis frame have been augmented while the weight has been considerably reduced. Lateral flexibility, said Mr. Hecox, is retained by mounting the rear springs on ball pivots at both ends, and the shackles at the rear ends of the front springs are longer and more flexible.

Chrysler Engine and Radiator Changes

Distinctive features of the Chrysler Motor Car Co.'s new products were briefly summarized by H. E. Maynard, who mentioned the change in radiator contour as the most striking among outward changes. He stated that internal-type hydraulic brakes are now in use on the entire line of Chrysler products.

Speaking of the engine, Mr. Maynard said that the changes have been confined largely to piston development. An L-shaped piston-ring is used on all the Chrysler company's cars now. This has a deep section of rather conventional width, with flanges approaching each other to within a distance of approximately 0.010 or 0.015 in. The result is an increase of wearing surface and better heat-conduction from piston-head to cylinder-walls, accompanied by greater oil economy. Incidentally, the piston-head is thicker than in the past and has a cone-shaped section so that the metal increases in thickness from the center to the sides. This arrangement, said Mr. Maynard, results in a cooler piston-head. The use of rubber in engine-mounting has been refined and, while relatively little rubber is used, a rigid support together with sufficient flexibility has been attained.

New Graham-Paige Features

Few changes are incorporated in this year's Graham-Paige line, said Louis Thoms, of that organization. Among its new features is the use, for the eight-cylinder engine, of dual ignition in which a double breaker-cam operates two coils, the effect being equivalent to that of two four-cylinder ignition systems. The engine is so mounted that rubber carries practically all the load in shear.

The four-speed transmissions are continued on all models except the smallest Graham-Paige. On that chassis the rear-axle housing is made from a piece of seamless tubing expanded at the center to receive the carrier assembly, and swaged down on the ends to a smaller diameter at the spring

seats and again upset on the ends for mounting the brake discs. As in the case of other car makes, frames have been stiffened; and the larger models have been equipped with Bijur chassis-lubrication.

Cadmium-Plating Used by Reo

The next speaker, F. C. Pearson, of the Reo Motor Car Co., told of the refinements incorporated in this year's Flying Cloud and in the Mate, which is virtually a smaller replica of the leader of the line. Cadmium-plating has been extensively introduced for such small parts as cap-screws, external chassis-bolts and corresponding parts of the body. The result, said Mr. Pearson, is a considerable saving on service bills. Corrosion is fought in other ways as well; for example, graphite is now being placed in the bronze bushings on the brake and clutch shafts. Rubber shackles employed at the spring ends are to minimize noise and lubrication trouble at these points.

Introduced by Chairman Barnard, F. S. Duesenberg, of Duesenberg, Inc., next answered questions propounded by members present. The first query concerned the gasoline mileage attained with the new car which has just been introduced by the Duesenberg firm. He stated that, while no exact check-up had yet been made on the engine of 3¾-in. bore, the car had shown 17 miles per gallon on the Indianapolis Speedway, at 25 m.p.h.

Special Duesenberg Features

Mr. Duesenberg then spoke of frame-stiffening as developed in his organization, and pointed out how the use of stronger and heavier material led to the use of a correspondingly heavier body on the chassis. With sample bodies, the cars now weigh from 4700 to 5200 lb. The engine, said Mr. Duesenberg, has 32 valves, operated by two camshafts. In developing this design, it has been his idea that fewer valve-grinding jobs would be required if two valves function alternately where ordinarily only one valve is used.

Rubber spring-shackles had been tried but Mr. Duesenberg had decided, after all, to use conventional shackles, with a ⅞-in. pin, 2½-in. springs, and bushings in both spring-ends made with a flange having a ⅜-in. face. These wide-flange bushings, faced on either side with good steel shackles, are rather expensive construction but not out of proportion in cost to other parts of the car.

Every bearing on the frame is Bijur-oiled, through the use of an automatic system which "shoots" the lubricant to every required point once in 70 miles. A system of lights shows the driver whether there is oil in the pressure line serving for chassis lubrication, or when the tank is empty.

Stutz Transmission Improvements

Among recent improvements of the Stutz Motor Car Co.'s product, which were mentioned by Bert Dingley, are one-shot lubrication, the introduction of springs in place of the rubber damper in the clutch, the use of a four-speed transmission, and the development of the Noback, an automatic-chuck device mounted in the rear of the transmission, which prevents the car from rolling back down a hill when the clutch and brake are disengaged. An improved brake-lining has been adopted, on the Stutz and the Blackhawk.

Poppet Exhaust-Valve Design

UNDER the title above, Gordon T. Williams, of the Thomson Products Co., gave an address before 46 members of the Buffalo Section gathered at the Hotel Statler on Feb. 19. Chairman E. W. Kimball presided during a brief business session at which a Nominating Committee for Section officers for next year was elected, as follows: J. W. White, E. W. Kimball, W. E. Laddon, A. F. Carlson, and W. R. Gordon.

W. E. John then accepted the chair and introduced Mr. Williams, who presented his paper, following which there was much discussion of the subject of exhaust valves. As the paper had not been received at the office of the S.A.E. Journal by the closing date for news copy for the March issue, no summary of it can be given, and the discussion is rather pointless without such a summary.

At the March 5 meeting of the Section, which is to be devoted to aeronautics, V. R. Jacobs, assistant manager of the aeronautics department of the Goodyear Tire & Rubber Co., is to give an address on Lighter-than-Air Ships. It was hoped that a dirigible airship could be brought to the city for the occasion, but no mooring mast or hangar facilities are available. The Section is endeavoring to arouse interest in the need for an airport for dirigible ships near the city. Mr. Jacobs' paper will relate to the plans of the Goodyear company for the building of two 6,500,000-cu. ft. helium-gas airships for the Navy and the construction of the world's largest hangar for use in assembling and housing the ships. W. R. Gordon, of the Pierce-Arrow Motor Car Co., will be in charge of the meeting.

Northern California Meeting

Members and Students Consider Body Forms, License Plates and Automobile Fans

THE meeting at the University of California held Feb. 14 by the Northern California Section was in conjunction with a meeting of representatives of student chapters of the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. It was preceded by a dinner at which Prof. C. E. Hyde, of the University of California, was toastmaster. In the course of his introductory speech, he remarked that this was the second annual meeting of this nature at the University.

Body Forms of Automobiles and Airplanes was the subject of the paper by Prof. Perham Nahl, of the University of California; and License-Plate Legibility was treated by W. L. Ingraham, a student at the University. Prof. V. C. George, of the University, presented a paper on Wind-Tunnel Tests to Determine the Best Type of Automobile Fan.

At the brief business session, the following members were elected to nominate officers of the Section for the ensuing year: Prof. L. Boelter, E. C. Wood, J. C. Bennett, Prof. A. B. Domonoske and O. R. Cole. The mechanical and electrical-engineering laboratories of the University were opened for inspection after the technical session adjourned.

Automobile and Airplane Bodies

Any form that man can devise must be suited to a certain element, said Professor Nahl. Nature has taken millions of years to develop certain forms most suitable for their particular environments. His theme was the finding of a parallel to such development by a careful examination of the development of the automobile and of the airplane.

In considering suitable body-forms for the automobile and the airplane, Professor Nahl suggested studying just what nature has done under similar conditions for similar requirements. He asked whether it is not true that the requirements produce the form and that, when the form fits the requirements perfectly, beauty is the result. For example, he noted how the former design of the automobile has changed from the high cumbersome body and large wheels to a design in which the car hugs the ground and the streamlining adds the element of beauty so that the appearance suggests speed and capacity. He compared also Wright's first airplane model with the

present airplane to show that the wings have become smaller and the entire machine more powerful. Suitability and beauty in automobile and airplane bodies will be attained only in accordance with what is demanded by the requirements for service, in his opinion.

License-Plate Legibility

It was stated by Mr. Ingraham that license plates make the collection of fees a simple matter by reducing the clerical force needed; they further the tracing of stolen cars; and they curb the hit-and-run driver. The essentials in designing license plates are that they must at all times be as visible and as readable as possible and, after having been perceived, the impression they convey must be retainable.

The speaker emphasized that contrasts are very important factors in a license plate. A color will appear darker or lighter depending upon the background upon which it is displayed. He described the usual experimental set-up for testing purposes in connection with design, and gave details of the tests made to determine the size, pattern, color and style of the plates and the lettering.

Determining a Suitable Fan Type

Professor George mentioned the numerous types of fan in use on automobiles and said that the problem becomes one of trying to find a fan which will best meet the demands of the individual automobile model. The quantity of air which the fan will deliver is of major importance, but other considerations such as the shape and number of blades and the speed of the fan in proportion to the engine speed must also be considered.

Wind-tunnel tests were made on a fan of 18-in. diameter. The size of the blade was uniform, it being 3 in. wide and 7 in. long, but the number of blades varied. Two, three, four, six and eight blades were used in the different tests, and the best results were obtained with a flat blade. Various curvatures of blade were tried, the ratio of the chord of the curve to the height of the arc varying from 20:1 to 5:1. Professor George showed the curves resulting from the data obtained with the flat blade, and explained their characteristics.

Since the fan is placed so that it can draw air through and enable the radiator to perform its function of cooling the water, the idea should be to draw in the maximum amount of air. Hence, the fan should be placed as close to the radiator as possible and the blades should be set at an angle such that they will deliver the quantity of air that is necessary for proper cooling under the varying conditions that may arise. The fan should be driven at a speed which will deliver this adequate quantity of air.

Truck Tire Change-Overs

Northwest Section Hears Dr. Stavely at Portland—Airplane Production Described at January Meeting

THE first official meeting of the Northwest Section held in the State of Oregon is characterized by Secretary A. M. Jones as a "most colorful and dramatic affair." About 125 members and guests attended the dinner and technical session at the Benson Hotel in Portland on the evening of Feb. 16. Among the attendants were city, county and State officials, including City Commissioner C. A. Bigelow; Multnomah County Commissioner C. S. Morse; J. A. Rafferty, head of the State of Oregon Traffic Department; and Capt. Frank Irwin, head of the City of Portland Traffic Department. Dr. J. W. Stavely, of the Firestone Tire & Rubber Co., came from Los Angeles to present a paper on Motorcoach and Truck Tire Change-Over from Solids to Pneumatics. The conclusions in the paper were supported by Ethelbert Favary, of Los Angeles, who reports that the meeting was a great success and believes one result will be an additional number of applications for membership. The members are very enthusiastic and eager to learn all they can.

City Commissioner Bigelow, the first speaker, represented the mayor of Portland and welcomed the visiting members to the city. Chairman Taylor, of the Section, outlined the work of the Society and the benefits accruing from standardization, then turned the meeting over to Vice-Chairman Baender.

Dr. Stavely explained and illustrated with drawings how change-over bands for pneumatic tires can be applied to wheel-rims for solid tires. He also spoke of the correct air-pressure for dual pneumatic tires, and recommended that the pressure in the outer and inner tires be equal. He discussed rated tire-loads and the damage done by overloading the tires.

General discussion brought out the fact that a change-over from solid to pneumatic tires on trucks is not always satisfactory, because the engine and the gear ratio would also need to be changed to obtain the maximum speed. Unless these changes are made, it is not possible to run the truck at a much higher speed than with the solid tires for which engine and gear ratio were designed.

Mock-Up Used by Boeing

At the January meeting of the Section, which was reported very briefly by telegram for the February issue of The Journal, Fred P. Laudan, of the Boeing Airplane Co., gave a very interesting talk on the production methods of that organization. Production in the automobile and the aeronautic industries are two entirely different things, he said. The airplane business is growing so fast and improvements or changes in airplanes are coming so rapidly that production of any one model has been going down from 200, for the Army Air Corps a few years ago, to 80, 73, 33, 27 and now to 10 for the Army and 27 for the Navy. A model that was uptodate six months ago is "out of the picture today."

Before the design of an airplane as conceived by the engineer goes into production, continued Mr. Laudan, a wooden mock-up of it is built. The parts are built of wood, to actual size, so that clearances of controls can be calculated, and the parts that must be most accessible are installed. Pilots are then asked to inspect the mock-up, noticing how the lower part of the plane clears the ground forward and at the rear; and often an engine is mounted at the front and a wooden coupling built around the exhaust manifolds. When making detail drawings, the engineers take their measurements from this full-size wooden model. Company officers also can see on it just how the parts they are most interested in are progressing. For instance, the sales manager, who is a pilot, can sit in the cockpit of the mock-up and see if the arrangement of the instruments suits him.

No Time To Test Real Model

The mock-up is necessary, because, unlike the automobile industry, the airplane builder has no time to build a real airplane of a new model and test it before going into production. For example, a lot of 25 Model-95 planes for the air-mail line had to be built without first constructing a model and testing it. To do this right up from the embryo conception in the engineer's mind and have an airplane that would be in perfect flying balance, that weighed just right to meet the Department of Commerce requirements and to carry a specified amount of mail, was no small problem. If it was 25 lb. over weight, the operating company would lose money on its contract because every time one of the 25 planes flew the 2000-mile route between Chi-

cago and San Francisco it would mean a loss of revenue of $1.50 per lb. on the 25 lb. for each 1000 miles.

Notwithstanding the building of the mock-up to actual dimensions, the company must furnish complete detail drawings to the Army and Navy, although the design may be built in a lot of only 75 or 100. These drawings are required by the Navy for use on airplane carriers and by the Army for use of the personnel with regard to parts.

Mr. Laudan then traced the operations from the detail drawings through the requirements section, issuance of blueprints to the shops, and the production section. He mentioned, in passing, that the Boeing Airplane Co. is now the Boeing Airplane & Transport Corp. and is soon to become the United Airplane & Transportation Corp., which will embrace all the organizations needed in the manufacture and commercial use of the airplane, including the Pratt & Whitney Aircraft Co., manufacturers of the Wasp and Hornet engines; radio engineers; the Boeing Airplane Co., manufacturers of airplanes; and the Boeing Air Transport Co., which holds the air-mail contract for the line between Chicago and San Francisco.

Ice Formation a Serious Problem

The company builds its airplanes and then tests them out on the air-mail route. One of the most difficult problems to solve is the formation of ice in the carbureter, which necessitates a forced landing. This occurs most often in night flying between Cheyenne, Wyo., and Chicago, particularly around Omaha. Most of the difficulty is caused by moisture in the air at temperatures between 24 and 32 deg. fahr. A hot-spot heater designed by the Pratt & Whitney engineers to be placed between the carbureter and the engine functioned perfectly, said Mr. Laudan, in a flight made by Pilot Leslie Tower at an altitude of 25,000 ft. above Seattle and Mount Rainier where temperatures as low as —40 deg. cent. (—40 deg. fahr.) were encountered, but it would not work under certain conditions on the mail route between San Francisco and Chicago. So a heater is now used that heats the air before it enters the carbureter, and this has solved the problem for the present.

At the conclusion of his address, a member inquired if any means has been found to minimize the accumulation of ice on the wings of an airplane. Mr. Laudan replied that this seems to involve the problem of heating, and any heating device increases the weight and reduces the pay-load. Nevertheless, if it is necessary to contend with ice, some way of preventing its formation must be employed, regardless of the cost.

Going to All-Metal Structure

Walter Jones, of the Boeing company, said in reply to another question that the company is using wooden wing-structure because it estimated that at least six months would be required to develop a metal structure and the metal would weigh a little more; however, as soon as the present lot of planes is gotten out, the company will return to the use of metal wings, and now has them ready for the next lot. For tail structures it is using channel-section beams of steel and ribs of duralumin, covered with a skin of the same material riveted to the trailing edge and sealed up as the last operation. This is protected against corrosion by a coating of pure aluminum. While this construction has its advantages, the interior cannot be inspected and treated for corrosion.

A peculiarity of the duralumin rivets used is, according to Mr. Laudan, that after they have been tempered in a salt bath at a certain temperature preparatory to use and have not been used within an hour or so, they become too hard even for setting with an automatic air riveter and must be retempered. Because of the close similarity by duralumin and aluminum, extreme care must be exercised to assure the use of the stronger alloy in the places specified. And where steel and duralumin join, red oxide primer coats are used as a precaution against corrosion and also as insulation to avoid interference with radio reception.

Design Changes and Operating Cost

Truck Makers Had Small Part in Reducing Overhauling Costs, Winchester Tells Pennsylvanians

SIXTY-THREE guests and 38 of the more than 200 members of the Pennsylvania Section attended the Feb. 19 meeting of that Section at the Hotel Adelphia in Philadelphia, which was preceded by a dinner and musical entertainment. Chairman A. Gelpke, presiding, welcomed the visitors and extended an invitation to attend all future meetings of the Section. He announced that the next meeting is to be held March 13 and will be presided over by C. O. Guernsey, who has arranged an interesting program on Diesel engines. A Nominating Committee to nominate Section officers for next year was elected as follows: Norman G. Shidle, C. O. Guernsey, C. A. McShane, F. O. Paul and L. E. Burgess. The chair was then relinquished to Donald B. Blanchard, who introduced W. J. Winchester, supervisor of motor-vehicles for the Standard Oil Co. of New Jersey, as the first speaker.

Want Simplicity and Accessibility

Mr. Winchester's topic was Engineering Features and Motor-Vehicle Design Which Affect Operating Costs. Although operating costs during the last few years have had a steady downward trend in well-organized operation, this cannot be credited entirely to engineering improvements, according to the speaker; we must also consider economic factors such as the use of equipment better suited to the work, better roads and better-trained personnel. It must be borne in mind, however, that advanced engineering plays an important part in enabling the operator to select vehicles of types from which more economical results can be had.

Transportation engineers engaged in the operation and maintenance of motor-trucks have for a long time urged simplicity of design and accessibility of parts, said Mr. Winchester; but by comparison with the changes in design of passenger automobiles in the last two or three years, the operators are convinced that many of the arguments advanced for more economical operation of passenger-cars have not been followed by the motor-truck builder. He acknowledged the great expense of redesigning vehicles and evolving superior new devices, but thinks that some organizations "stand pat" too long and do not attempt to adopt some of the later devices that operators find economical.

A number of slides of two-wheel and four-wheel-drive trucks and of crawler-tread tractors were thrown on the screen to show some of the conditions under which trucks operate and types of equipment produced to meet the requirements. In all types of equipment the operators are all looking for simplicity in design and for reliability of the units. It is probable, thinks Mr. Winchester, that in a short time the truck operator will be able to secure the benefit of better balanced engines, perhaps of six or eight cylinders. Today he adheres to the four-cylinder type because of the advantages of interchangeability within the fleet. Speaking of the modern design of demountable cylinder-head versus the valve-port type, he said that a man who has had supervision of repair work on a number of engines with the new type of head recently asked to have the old type of demountable head sent to him, because with them it is not

necessary to tighten the gaskets after the valves are ground in. Valves, said Mr. Winchester, perform much more satisfactorily than they did 8 to 12 years ago, probably because of the use of better valve material and better understanding by the operators of the fuel requirements and the necessity of lubrication.

Fuels and Oils Better

We have better-balanced fuels than formerly, thinks Mr. Winchester, with a little lower initial starting-point and a boiling-point that is not so high; the result being better combustion. He mentioned seeing a few days previously a 7-ton truck, hauling a 2000-gal. tank and trailer, that had covered 40,000 miles without having the valves ground.

Mr. Winchester stated that he has no knowledge of a truck builder advocating higher engine-compression, and knows that various of the different special fuels in the market cannot be used advantageously without making certain carbureter adjustments. Therefore he questions if it pays to keep changing experimentally from one fuel to another.

Distinct advances have been made in lubricants, he said, as a result of dilution studies made by the Society and the Bureau of Standards. Devices have been developed to overcome dilution and to reduce the oil consumption, and the oil manufacturer now knows more about the requirements of the internal-combustion engine.

Rigid Frames Break

American practice is largely going to rigid chassis frames, but with the non-rigid frames operated under Mr. Winchester's supervision there has been less breakage than with the rigid type. Frames are likely to twist under the heavy loads carried and the uneven condition of roads or ground, and the distortion results in frame breakage and other difficulties if the frame is rigid. Similarly, although the rigid type of body has been rather generally adopted, study of weight distribution, material and construction made it possible to construct a steel body having greater durability for a given weight than bodies built of any other material. There is need, according to the speaker, for the Society to study the relation of body weight to rated chassis capacity and to put out a table of weights that will be more in conformity with actual commercial practice than the body-weight allowances established years ago by the National Automobile Chamber of Commerce. He thinks also that the Society should study body dimensions so that these can be standardized to facilitate the interchanging of bodies on different chassis and preserve proper distribution of the load.

Frameless Tank-Truck Shown

A novel "frameless" tank-truck of about 2400-gal. capacity was shown in one of the slides. This was built finally after a great deal of difficulty in getting certain manufacturers to work out the design. One of these interesting experimental trucks has run approximately 70,000 miles and another has run 30,000 miles. The trucks haul trailers, the combined capacity of the truck and trailer being 7000 gal. Rubber shock-absorbers are used in the truck fifth-wheel and in the rear spring-hangers. The design has reduced operating costs, as it has been possible to haul about one-third greater loads. Where the State laws permit, the six-wheel unit hauls a four-wheel trailer, and it is possible to make a large saving as against freight rates.

In another slide, Mr. Winchester showed the fluctuations of tank sizes built from 1922 to 1927 by one manufacturer, and pointed out that production of the small size for Ford chassis has dropped away down while the numbers of larger units have increased, showing that the oil companies, like most other concerns, are going to larger units, which results in fewer vehicles being operated and lower unit cost of haulage for a given gallonage or tonnage.

A new development illustrated was a tank truck for fueling airplanes. High-grade fuel is pumped up through a meter to the airplane tank, no cans being used. Lubricating-oil tanks are carried at the sides of the fuel tank, and an air-pump is provided for inflating the airplane tires. Water can also be supplied, if necessary.

Another development shown was a tank mounted on a three-point suspension on the chassis, which has proved very successful in avoiding frame breakage in the larger trucks. Three-point suspension of cabs also has prolonged the life of the cabs.

The remainder of Mr. Winchester's address was devoted to repair-shop methods and equipment which have had much to do with reducing motor-truck operating costs. These were liberally illustrated with lantern slides. Among the subjects dealt with were dynamometer testing of overhauled engines, brake-lining tests, crane lifts, engine reconditioning tools, washing and painting methods, and chassis record-form.

Overhauling Costs Greatly Reduced

In conclusion, Mr. Winchester said that, as a result of improvement in design and the shop methods and equipment mentioned, his company is now effecting savings on 2½-ton trucks as follows, compared with costs in 1922: engine overhauling, 36 per cent; transmission overhauling, 27 per cent; front axle, 38 per cent; rear axle, 67 per cent; chassis, 1.4 per cent; body and cab, 54 per cent; and electrical work, 56 per cent.

Discussion following the conclusion of the address was participated in by B. B. Bachman, of the Autocar Co.; V. B. Phillips, Philadelphia branch manager of the General Motors Truck Co.; and W. J. Baumgartner, chemical engineer of the Relay Motor Corp. These discussers dealt mainly with the importance of operating and maintenance engineering and of university training along this line; the question of higher speeds and the use of speed governors; and the rating of chassis by gross weight with body and load instead of by tons of load capacity.

Thermostatic Control of Mixture

Automatic Regulation of Starting Mixture and Running Temperature Discussed by New England Section

PAST-CHAIRMAN Merl R. Wolfard, of the New England Section, who is engineer in charge of the Hopewell Brothers' research laboratory in Watertown, Mass., presented a paper on carbureters, with special reference to thermostatic control, at the Feb. 13 meeting of the Section in Boston. G. L. Appleyard served as Chairman of the meeting, which opened with the election of a Nominating Committee for officers of the Section for the coming year. The Committee consists of Past-Chairman Wolfard, Chairman R. W. Brown, Dean A. Fales, L. W. Martin and Frank Johnson.

After an introduction in which he said that no other part of the automobile offers greater opportunity for improvements than the carbureter, Mr. Wolfard presented charts showing the required ratio of fuel and air in an engine during light running and at low operating-temperature, the range of explosibility of gasoline and air mixtures, temperature drop due to vaporization of gasoline, and change in efficiency of the engine with increasing intake-air temperatures.

Slides of several typical carbureters were then thrown on the screen, and their design and operation were discussed with particular reference to their adaptability to thermostatic control. The constant-pressure type is found to be unsuitable for this purpose,

because any increase in the fuel would be constant rather than proportional over the operating range.

The so-called plain-tube carbureter, with venturi, is also found by the speaker to be unsuitable, because the intermediate passage cannot be controlled. The auxiliary air-valve type he concluded to be most suitable, as well as being the type that is generally found to give the greatest mileage per gallon of fuel.

Thermostatic Control Devices

Turning to the actual development of thermostatic control, Mr. Wolfard said that the first patent on the subject in this Country was applied for about 1911 and granted in 1915. This control was attached to a constant-pressure type of carbureter. The device consisted of a spiral thermostat adapted to rotate a gear which changed the relative position of the needle-valve by means of a screw-thread. Several other devices were shown, attention being called to the danger from wear in a thread that is subjected to constant turning back and forth.

One of the details shown was a double-spiral thermostatic coil, developed in the Hopewell laboratory, which is said to give a considerable angular movement with much greater force than the usual single coil because of the elimination of the high bending-moment opposite the point of attachment of the outermost coil. This coil is used in a control that is linked to the carbureter in such a way that a choking effect proportional to the temperature is given during starting, and a cold-air valve is gradually opened when the normal-running temperature is exceeded. While this device is not claimed to be precise in its operation, it is said to control the mixture while starting and to give a very close approximation of a constant intake-air temperature during the normal operation.

The Whatmough automatic control of the intake-air temperature, as shown in connection with Maurice Platt's paper in The Journal for September, 1928, p. 303, was described and found wanting, in that it controls only the temperature of the air, not the richness of the mixture during starting.

Discussion of the paper showed that some of the operators present are interested in the economy that may be secured by thermostatic control. Mr. Wolfard said that most carbureters are adjusted for too rich a mixture, because the operators otherwise are not satisfied with the operating conditions immediately after starting. On this account, he believes that 20 to 25 per cent increased mileage can be secured from gasoline by automatic control. In addition, crankcase-oil dilution and carbon deposits will be reduced.

Fuel and Oil Meeting

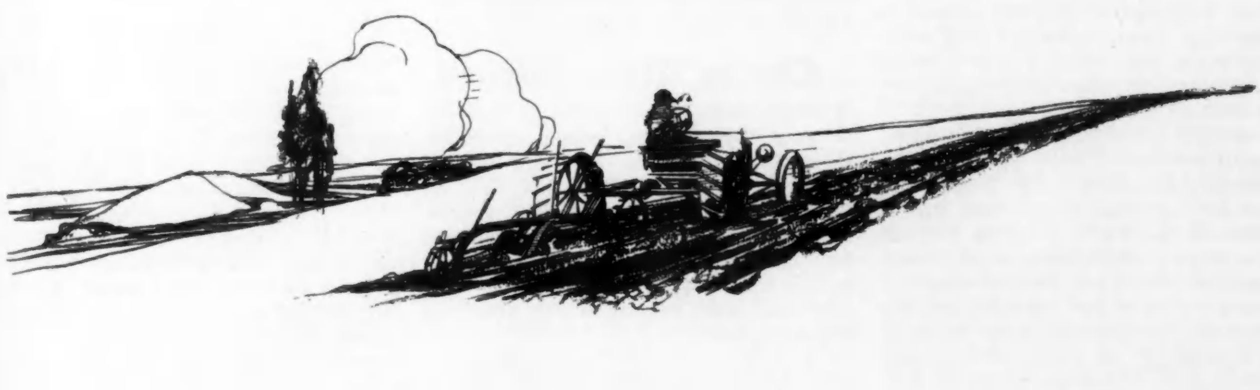
LUBRICANTS and fuels were the subjects of two papers read at the meeting held Jan. 31 by the Washington Section following a dinner at the City Club. The attendance totaled 50. Thomas Neill, Chairman of the Section, presided. A paper on Fuels and Fuel Testing was presented by Donald B. Brooks, and one on Motor Lubricating Oils, by Dr. Roy J. Kennedy, both of the Bureau of Standards.

Delivery of the papers was followed by a spirited discussion, in which the following men took part: H. K. Cummings, of the Bureau of Standards; A. Preston Petre, of the American Hammered Piston Ring Co., Baltimore; Carlyle S. Fliedner, of the Bureau of Aeronautics; George O. Pooley, of the Chesapeake & Potomac Telephone Co. & Associated Companies, City of Washington; and Edward S. Pardoe, of the Capital Traction Co., City of Washington.

Canadian Section Banquet and Meeting

FIFTY-FOUR members of the new Canadian Section attended the banquet and meeting held the evening of Feb. 13 at the King Edward Hotel in Toronto. Some of the members came from as far east as Ottawa and as far west as Ingersoll. Chairman R. H. Combs presided. The speakers were W. J. Davidson, of the General Motors Corp. technical committee, Detroit; O. T. Kreusser, director of the General Motors Proving Ground, Milford, Mich.; and C. H. Carlisle, president of the Goodyear Tire & Rubber Co.

The next meeting of the Section is to be held on March 13, and by popular vote at the last preceding meeting it was decided that all meetings shall be dinner meetings.



Alexander T. Brown

A LONG and active life came to a close when Alexander T. Brown, president of the Brown-Lipe Gear Co. and known internationally as an inventor and engineer, died in Syracuse, N. Y., on Jan. 31, following a period of failing health. Mr. Brown had not only been connected with automotive manufacturing since the very early days of the industry, but had gained fame and fortune through the invention and development of the L. C. Smith shotgun and the Smith-Premier typewriter.

Mr. Brown's 74 years of life were representative of a constructive and successful American career. He was born on a farm at Scott, Cortland County, N. Y., in November, 1854, of Revolutionary stock. As a mere boy, he showed signs of the mechanical genius and the quality of leadership on which his later accomplishments were built. His technical education was acquired at Homer Academy. Having already worked as agent for a harvester-machine concern, he went to Syracuse at the age of 23 and his first job in the city was with the W. H. Baker firearms firm, for which he produced the L. C. Smith shotgun. From 1879 to 1895 he was connected with the L. C. Smith Typewriter Co.

With a rare instinct for the technical needs not only of today but of tomorrow, Mr. Brown devoted considerable attention to the development of several telephonic and automotive devices. Hence, it was practically a foregone conclusion that the early rise of the automobile industry would beckon irresistibly to him. One of the founders of the H. H. Franklin Co., of Syracuse, he remained with that company until 1906 and at one time was its president. Early in the twentieth century he also formed a connection with the W. C. Lipe machine organization, outgrowths of which were the Brown-Lipe Gear Co. and the Brown-Lipe-Chapin Co., which later became a subsidiary of the General Motors Corp.

Recently, in addition to the presidency of the Brown-Lipe Gear Co., Mr. Brown held the presidency of the Globe Forge & Foundries, Inc., and was a director of the First Trust & Deposit Co., a trustee of Syracuse University and of the New York State College of Forestry. Since the creation of the State Grade Crossing Commission in 1911, and until 1925, he was a member of that body and for 13 years its chairman.

Mr. Brown was one of the oldest members of the Society, having been elected a Member in February, 1909, and was a member of the Transmission Division of the Standards Committee during the years 1917, 1918, and 1919. He was also a member of the Buffalo Section of the Society. He was a life member of the American Society of Mechanical Engineers and was affiliated with various other technical, social and benevolent organizations. He is survived by his widow, Mrs. Mary Seaman Brown, two sons, Charles S. Brown and Julian S. Brown, and a brother, William H. Brown.

Harold Brooks Winchell

THE automotive industry lost an esteemed and progressive member in Harold B. Winchell, chief engineer of the John W. Brown Mfg. Co., of Columbus, Ohio, who after three months' illness succumbed on Jan. 31.

Mr. Winchell was born in June, 1894. After graduating from high school, he studied electrical engineering at the University of Michigan, from 1913 to 1917. Having received the degree of B. S. E. in June, 1917, he accepted a position with the American Telephone & Telegraph Co. in New York City, to conduct a student course in the plant department. In December of the same year he was engaged by the American International Shipbuilding Corp., at Hog Island, Pa., and remained with that company as assistant progress engineer until April, 1919, when he joined William & Harvey Rowland, Inc., in Frankford, Pa., as engineer in the firm's automobile-spring manufacturing business.

Mr. Winchell was elected a Junior Member of the Society in December, 1918, and in June, 1924, was transferred to Member grade.

Charles Arthur Bennett

FOLLOWING an operation necessitated by an acute attack of appendicitis, Charles A. Bennett passed away at Honeoye Falls, N. Y., on Jan. 4. He is survived by his widow, Mrs. Martha G. Bennett, and mourned by his numerous friends in the automotive industry, with which Mr. Bennett had been connected for nearly a score of years.

Born at Norwich, N. Y., in October, 1881, Mr. Bennett amplified his high-school education by studying the mechanical-engineering courses of the International Correspondence Schools. His industrial experience began in 1902, when he became general machine apprentice with the Conger Mfg. Co., of Groton, N. Y. Two years later he joined the International Harvester Co.'s organization at Auburn, N. Y., where he remained until 1906, when he became affiliated with the McIntosh-Seymour Co., of the same city.

From 1907 to 1911 Mr. Bennett was connected with the Gleason Works, of Rochester, N. Y., and in the engineering department gained a great deal of valuable experience in demonstrating, testing, cutting and inspecting differential drive and rear-axle construction. This work led to his specializing in the gear field and to his connection, in 1912, with the Fellows Gear Shaper Co., of Springfield, Vt., as transmission-gear specialist and general consulting engineer. From 1912 to 1915 he was the Fellows company's foreign mechanical engineer and European sales director, located in Paris. His headquarters of late years have been in Detroit. He remained active in the organization up to the time of his death.

Mr. Bennett became a Foreign Member of the Society in 1915, and in 1923 was transferred to Member grade following his return to this Country.

Edward Owen Sutton

A VETERAN of the automotive industry was lost by it and the Society lost a long-time member with the passing on of Edward Owen Sutton, treasurer of the Knox Motors Co., of Springfield, Mass., on Dec. 3, 1928.

Born at Bedford, N. Y., in 1871, Mr. Sutton received his technical education at the Sheffield Scientific School of Yale University, from which he was graduated in 1891 with the degree of bachelor of philosophy. For some years he was connected with the Fisk Rubber Co., of Chicopee Falls, Mass., but later joined the Knox Automobile Co., in Springfield. Mr. Sutton was assistant to the general manager of the Knox company at the time of his election as a Member of the Society in 1912, and during the succeeding 17 years rose to the position of treasurer. He was for many years also a member of the New England Section.

Personal Notes of the Members

Moskovics Retires

Of marked interest to the automotive industry was the recent announcement that Frederick E. Moskovics had resigned as president of the Stutz Motor Car Co. of America, Inc., to devote more time to personal affairs.

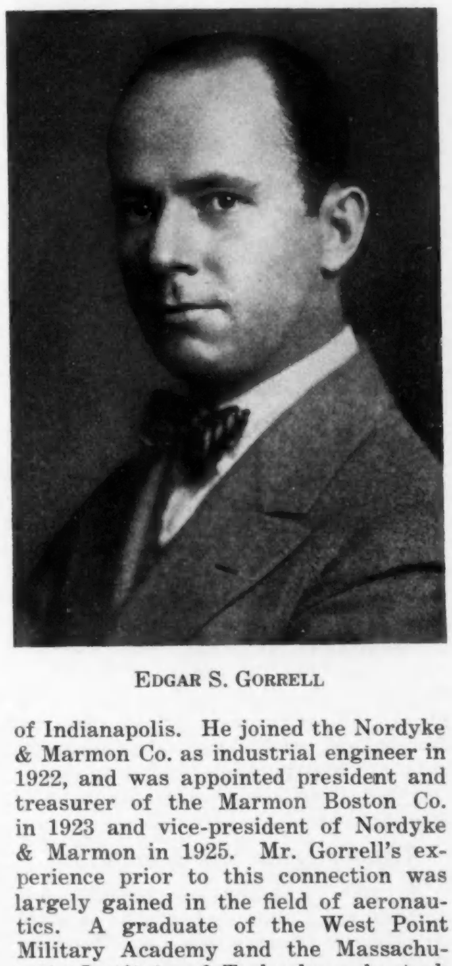
Mr. Moskovics, who was born in Budapest, Hungary, came to this Country in early childhood. After studying at Armour Institute of Technology and in Europe he entered the automotive field: first in Europe with Daimler; then in this Country with the Continental Tire Co, and as partner with Brandenburg Bros., designing, manufacturing and selling automobile parts. In 1907 he became general manager of the Kingston Motor Car Co., and in that year he designed his first automobile, the Allen-Kingston. Subsequently, he was connected with the Remy Electric Co., at Anderson, Ind., as sales manager, and in 1913 he became associated with the Nordyke & Marmon Co., in Indianapolis, as commercial manager, afterward becoming vice-president of the company. In 1924 he assumed the vice-presidency of the Franklin Automobile Co., and in 1925 became president of the Stutz Motor Car Co.

Mr. Moskovics was elected to membership in the Society in 1908 and has been a member of the Indiana Section since 1915, except during the year 1924, the time of his association with the Franklin Company, when he belonged to the Metropolitan Section. His activities as an S.A.E. Member have been of inestimable value to the Society. In 1917 he served as Councilor, and the same year was also appointed to membership on the National Meetings Committee and the Governing Committee of the Indiana Section. The following year he was re-elected to serve on the Meetings Committee and later was chosen Chairman of the House Committee and a member of the S.A.E. Simplified Practice Committee. Last year he acted as Chairman of the Constitution Committee and is now Chairman of the Reorganization Committee, which has under consideration a number of changes in the Society organization.

He is the author of many technical papers of outstanding interest and engineering value, among which are the following: Influence of the Sales Department on the Design of Motor Cars, published in the BULLETIN of May, 1913, and in Part II of TRANSACTIONS for that year; Relation of the Magneto to Engine Design, printed in Part I of TRANSACTIONS for 1912; The Engineer's Place in the Industry, which appeared in the May, 1921, issue of THE JOURNAL; and Two Kinds of Engineering, published in THE JOURNAL of July, 1923.

Gorrell New Stutz President

Edgar S. Gorrell, formerly vice-president of the Stutz Motor Car Co. of America, Inc., has been elected to succeed F. E. Moskovics as president. The new president became associated with Stutz in 1925, following his resignation from the Nordyke & Marmon Co., also of Indianapolis. He joined the Nordyke & Marmon Co. as industrial engineer in 1922, and was appointed president and treasurer of the Marmon Boston Co. in 1923 and vice-president of Nordyke & Marmon in 1925. Mr. Gorrell's experience prior to this connection was largely gained in the field of aeronautics. A graduate of the West Point Military Academy and the Massachusetts Institute of Technology, he took up flying in 1914 in the service of the United States Army, and in 1916 won distinction as an Army aviator. During the World War, as a lieutenant-colonel, he acted as chief of the technical division of the American Expeditionary Forces in France. Later, with the rank of colonel, he was appointed chief of staff of the Air Forces. In recognition of his war services, Colonel Gorrell received American, British and French decorations.



EDGAR S. GORRELL

Colonel Gorrell joined the Society in 1916 as a Junior Member and, in 1922, was transferred to Member grade. Air Navigation is the subject of an interesting paper contributed by him to Society literature, and published in the November, 1920, issue of THE JOURNAL.

Berry Leaves Buick

On the first of the year O. C. Berry resigned from the Buick Motor Car Co. to enter upon his connection with the Borg-Warner Corp., as director of engineering. His headquarters will be located at Flint, Mich.

Mr. Berry acquired his technical education at the University of Michigan and the University of Wisconsin, receiving the degrees of Bachelor of Science and Mechanical Engineer. He conducted a study of gas producers as a graduate student at the University of Wisconsin, and also acted as instructor in the engine laboratory of that university. He subsequently taught at Purdue University for about nine years, being appointed assistant professor in 1914, associate professor in 1917, and professor in 1920, of gas and automotive engineering. He resigned from the faculty of Purdue in 1921 to enter the commercial field, as research engineer for the Hupp Motor Car Co., of Detroit. The following year he was made chief engineer of the Wheeler-Schebler Carburetor Co., in Indianapolis, and held this post until March, 1927, when he became identified with the engineering department of Buick.

During his membership, which dates back to 1920, Mr. Berry has been a prominent figure in the work of the Society. This year he was elected Second Vice-President, representing Motor-Car Engineering. He has been a member of the Research Committee every year since 1922, and is now entering upon his fourth consecutive term of service on the Fuels Subcommittee of the Research Committee. In 1923 he was on the National Meetings Committee, and has twice been a member of the Publication Committee. For several years he has been a member of the Cooperative Fuel Research Steering Committee, and is serving in this capacity again this year.

Mr. Berry's Section activities have been no less noteworthy than his National work in the Society. He joined the Indiana Section in 1921, when he was elected Chairman of the Section,

and subsequently served two terms as Vice-Chairman of his Section.

Various papers of unusual merit have been presented by Mr. Berry at Section and National meetings, including the following: A Standard of Carbureter Performance, published in the February, 1917, BULLETIN and in Part I of the corresponding TRANSACTIONS; Mixture Requirements of Automobile Engines, printed in the November, 1919, issue of THE JOURNAL and in Part I of TRANSACTIONS for 1920; and More Car Miles per Gallon of Fuel, which appeared in THE JOURNAL of August, 1922, and in Part II of TRANSACTIONS for the same year. Manifold Vaporization and Exhaust-Gas Temperatures, a paper written in collaboration with C. S. Kegerreis, was published in the March, 1922, issue of THE JOURNAL and in Part I of TRANSACTIONS for 1922.

An abstract of a talk on the practical effects of too low volatility, which Mr. Berry delivered at the Fuel Session of the joint meeting held in Chicago in December, 1921, at which representatives of the Society, the National Automobile Chamber of Commerce and other automotive interests conferred with members of the American Petroleum Institute, is contained in THE JOURNAL for January, 1922.

Dresser With New Company

Sidney R. Dresser has embarked on a new venture in becoming associated with the Kent Garage Investing Co., which was recently organized in New York City. Mr. Dresser, who accepted his first automotive position as research engineer with the New York Edison Co., thus continues his interest in power and commercial engineering, which was awakened while he was a student at Cornell University. Leaving the Edison Company a year later, he joined the United Electric Light & Power Co., also of New York City, as power engineer to take charge of commercial engineering.

In 1916 the Read-Dresser Engineering Co. was formed, and Mr. Dresser was elected secretary and treasurer. His work was interrupted by the outbreak of the World War, during which he joined the equipment division of the Signal Corps in the United States Army and assumed charge of electrical inspection and production in the East. His duties included the general organization of inspection forces, the engineering supervision of contracts and the approval of materials. At the close of the war he became affiliated with the New York division of the Whitney Blake Co., of New Haven, Conn. As automotive cable engineer, he supervised the design, sales, and application of automotive electrical wire and cable. He was made chief cable engineer in 1927 and retained this position until the recent severance of his connection with the organization.

Mr. Dresser, as executive engineer of the Kent Company, is now connected still more closely with automotive work. His company has just completed the first New York City unit of a chain of 25-story high-speed garages to be erected in the big centers. These garages house 1100 cars and will be a means of relieving traffic congestion by providing convenient economical means of parking cars in business areas.

SIDNEY R. DRESSER

Mr. Dresser has taken a prominent part in Society activities since becoming a Member in 1923 and a Metropolitan Section member in 1924. He served on the National Meetings Committee last year and has consented to serve again this year. In 1927 he was a member-at-large of the Sections Committee and Chairman of the Nominating Committee, and in 1928 was chosen Vice-Chairman of his Section. At present, under his able chairmanship, the Metropolitan Section is carrying out a most successful program of meetings.

Tilley Forms New Connection

Norman N. Tilley was recently appointed chief engineer of the Kinner Airplane & Motor Corp., at Glendale, Calif. His engineering experience in the aeronautical field forms a more than adequate background for his new work. Upon completion of an engineering course at Cornell University in 1915, he was appointed instructor in mechanical engineering at the university. In 1917 he joined the Air Service of the United States Army, acting as an instructor in the subject of aviation engines. He subsequently became an airplane pilot and officer in charge of the erection and repair of airplanes at the Air Service Mechanics School. In 1920 he accepted the post of professor of mechanical engineering at the New Mexico College of Agricultural and Mechanical Arts, at State College, N. M. Then followed a year of instruction in mechanical engineering at the University of Texas, which he left to engage in the development of aviation engines at McCook Field, Dayton, Ohio. He was later appointed chief of the aircraft engine development and specifications unit of the powerplant branch, which position he lately relinquished to become affiliated with the Kinner Airplane & Motor Corp.

Mr. Tilley joined the Society, as a Service Member, in 1922, and the Dayton Section in 1925. This year he was chosen Treasurer of his Section.

Woman Engineer Retires

Nellie Scott Rogers, following a long and distinguished service in the automotive industry, has disposed of her interests in the Bantam Ball Bearing Co., located at Bantam, Conn., and has announced her intention of taking a much-needed rest. Mrs. Rogers has been treasurer of the Bantam Ball Bearing Co. for the last 25 years, and is widely known as an expert accountant and financial manager. She is one of the few women in this Country who have been accorded the honor of membership in an engineering society. In 1920 she was elected Associate Member in the S.A.E., and is one of the six women Associate Members of the American Society of Mechanical Engineers.

Paul C. Ackerman, of the Timken Roller Bearing Co., at Canton, Ohio, has been appointed assistant chief engineer of the company. He previously acted as service engineer.

Gerald H. Allen recently resigned as president of the Ajax Electric Co., in Kalamazoo, Mich., to assume the presidency of the Allen Electric & Equipment Co., also located at Kalamazoo.

Horace R. Allen, who until recently was chief tool and die designer for the Oakes Co., Indianapolis, has accepted a position as chief tool engineer with the Drafting Service Co. of the same city.

D. P. Bisbee, who until lately was design engineer for the Bowen Products Corp., at Pasadena, Calif., is now acting in a similar capacity for the F. & F. Six Wheel Corp., of Los Angeles.

Clement A. Borton has been promoted from service manager to general manager of the Autocar Sales & Service Co., of Boston.

Enea Bossi, formerly president of the Société Continentale Parker, in Clichy, Seine, France, was lately appointed president of the American Aeronautical Corp., New York City.

(Concluded on p. 36)

Applicants Qualified

The following applicants have qualified for admission to the Society between Jan. 10 and Feb. 10, 1929. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

Abert, Hamilton (A) secretary, assistant factory manager, Manhattan Rubber Mfg. Co., 61 Willett Street, *Passaic, N. J.*

Adams, Arthur A. (F M) member board of directors, National Aircraft Industries, Aviatrest, *Moscow, U. S. S. R.;* (mail) "Aviatrest" B, Tcherkasky 2.

Arbour, Everett J. (A) co-partner, Joseph Arbour & Son, 56 Whiting Street, *New Britain, Conn.*

Archibald, J. R. (A) 4112 Hurst Street, via New Westminster, *Burnaby, British Columbia.*

Ashby, William L. (A) aviation sales engineer, Tide Water Oil Sales Co., 11 Broadway, New York City; (mail) 83 Peddie Street, *Newark, N. J.*

Averill, Frank B. (M) factory manager, Durant Motors of Canada, Ltd., Leaside, *Toronto, Ont., Canada.*

Baldwin, Leonard C. (A) motor sales engineer, Standard Oil Co. of New Jersey, 185 Washington Street, Newark, N. J.; (mail) 22 East 12th Street, *Bayonne, N. J.*

Barth, William (M) designer, General Motors Research Corp., *Detroit;* (mail) 1-213 General Motors Building.

Bartelтт, K. J. G. (F. M.) technical foreign sales representative, Bristol Aeroplane Corp., Ltd., *Bristol, England;* (mail) Filbon House.

Beckhard, Bruno (M) Outboard Motor Headquarters, Flushing Bridge, *Flushing, L. I., N. Y.*

Beisel, Rex B. (M) chief designer (aircraft), Curtiss Aeroplane & Motor Co., Inc., *Garden City, L. I., N. Y.*

Bentley, Alexander Norton (A) manager, Exide Batteries of Canada, Ltd., 153 Dufferin Street, *Toronto, Ont., Canada.*

Berry, John Hatton (F M) production manager, General Motors Export Co., Broadway and 57th Street, *New York City.*

Blackburn, Robert Hickman (A) proprietor, Blackburn Oil Co., Glendalyn Street, *Spartanburg, S. C.*

Blackeby, F. Walter (A) sales engineer, Dodge Steel Co., 6501 Tacony Street, *Philadelphia.*

Borruat, Luis A. (J) Escuela de Artos y Officios de La Nacion, Argentine Republic; (mail) Pedro N. Carreras 666, Tres Arroyos F. C. S., *Argentine Republic, South America.*

Brackett, C. L. (A) president, general manager, National Machine Products Co., 4850 Bellevue Avenue, *Detroit.*

Brennen, James (A) president, manager Piston Service, Inc., 801 East Pike Street, *Seattle, Wash.*

Burwell, Walter T. (J) specification engineer, Tillotson Mfg. Co., *Toledo, Ohio;* (mail) 4244 Burnham Avenue.

Carron, Iris (J) checker, body engineering department, Chrysler Corp., *Detroit;* (mail) 65 West Parkhurst Place.

Chace, Thomas B. (A) salesman, Dole Valve Co., 1933 Carroll Avenue, *Chicago.*

Cohee, H. H. (A) service manager, Mack International Motor Truck Corp., Tacoma, Wash.; (mail) R. F. D. 3, *Seattle, Wash.*

Davies, George C. (J) research engineers' assistant, Standard Oil Development Co., *Elizabeth, N. J.;* (mail) 887 Magie Avenue.

Day, James Robert (M) chief draftsman, Wyman-Gordon Co., Ingalls-Shepard Division, *Harvey, Ill.*

DeCamp, Robert Benjamin (J) superintendent, maintenance, DeCamp Bus Lines, Mount Pleasant Avenue, *Livingston, N. J.*

DeSilva, W. B. (A) service engineer, Larrabee-Deyo Motor Truck Co., Inc., *Binghamton, N. Y.;* (mail) 7 Wayne Avenue.

Dieter, William (M) engineer, E. W. Bliss Co., 53rd Street and Second Avenue, *Brooklyn, N. Y.*

Dimm, Ira Lloyd (A) sales manager, appraiser of exchanged cars, Rolls-Royce of America, Inc., 58th Street and Eighth Avenue, *New York City.*

Dunnigan, M. A. (M) engineer, W. H. Barber Co., 1501 Franklin Avenue, South East, *Minneapolis.*

Faroux, Charles (F M) editor, *La Vie Automobile*, 92 Rue Bonaparte, *Paris VI^e, France.*

Frey, George (A) general sales manager, J. G. Brill Co., 62nd Street and Woodland Avenue, *Philadelphia.*

Griffin, Howard A. (M) mechanical engineer, Chrysler Corp., 341 Massachusetts Avenue, Detroit; (mail) 111 Highland Avenue, *Highland Park, Mich.*

Groh, Julius A. (F M) body engineer, Ceskomorauska - Kolben - Danek, *Prague, Czechoslovakia;* (mail) Smichou, Zborouska 66.

Hamilton, Ernest E. (J) mechanical draftsman, Fisher Body Corp., Plant 33 M, *Detroit;* (mail) Room 215, State Hotel, Second Boulevard and Milwaukee.

Harrigan, Daniel Ward (S M) lieutenant, engineering officer, VB Squadron One-B, Fleet Air Base, *San Diego, Cal.*

Harris, William W. (A) patent counsel, Continental Motors Corp., 12801 Jefferson Avenue, East, *Detroit.*

Hartman, Eugene L. (A) treasurer, assistant general manager, Hartman Supply Co., 210 Blackman Street, *West Pittston, Pa.;* (mail) 201 Luzerne Avenue.

Hartnett, C. M. (A) superintendent, Dairy Dale Co., 3550 19th Street, *San Francisco;* (mail) 195 Second Avenue.

Hatch, I. N. (M) service manager, Stutz Motor Car Corp., Chicago factory branch, 2912 Vernon Avenue, *Chicago.*

Hendrickson, N. Edwin (M) vice-president, Mather Spring Co., *Toledo, Ohio.*

Herbert, Howard D. (A) Firestone Tire & Rubber Co., *Akron, Ohio;* (mail) 666 Weber Avenue.

Hill, Henry Clinton (J) test engineer, Wright Aeronautical Corp., Paterson, N. J.; (mail) 838 Bloomfield Avenue, *Montclair, N. J.*

Hofmann, Max (M) research engineer, Waukesha Motor Co., *Waukesha, Wis.;* (mail) 222 Randall Street.

Hopkins, George D. (M) president, Hopkins Mfg. Co., *Hanover, Pa.*

Hotchkiss, Grosvenor (M) engineer, Western Union Telegraph Co., *New York City;* (mail) care Vice-President, Traffic, Western Union Telegraph Co., 195 Broadway.

Jones, Reginald Fairchild (A) assembly superintendent, Melbourne Motor Body & Assembly Co., Proprietary, Ltd., *Victoria, Australia;* (mail) 38 Rathmines Road, Auburn, E. 3.

Komarnitsky, Rostislaw S. (J) assistant to chief engineer, in charge of engineering department, New Standard Aircraft Corp., 230 East 16th Street, *Paterson, N. J.*

Kullmann, Earl L. (J) assistant superintendent, Wadhams Oil Co., *Milwaukee;* (mail) 50 48th Street.

Lambert, Arthur R. (J) draftsman, Gates Day Aircraft Co., *Paterson, N. J.*

Leggat, John W. (M) chief draftsman, chassis division, Oakland Motor Car Co., Pontiac, Mich.; (mail) 14885 Greenview Avenue, *Detroit.*

Leslie, John C. (J) assistant in Mr. Fokker's office, Fokker Aircraft Corp. of America, Hasbrouck Heights, N. J.; (mail) 360 Main Street, *Hackensack, N. J.*

Linneen, H. W. (A) manager, lubricating sales, Sinclair Refining Co., *Atlanta, Ga.;* (mail) 1161 Orme Circle.

Loose, Theron L. (M) general superintendent, Indian Motocycle Co., *Springfield, Mass.*

Losowich, W. C. (J) experimental engineer, Eclipse Machine Co., East Orange, N. J.; (mail) 800 Park Avenue, *Hoboken, N. J.*

Luckey, Lester Eugene (A) president, general manager, Eugene Luckey, Inc., 100 North Broadway, *Portland, Ore.*

Mahoney, J. Allan (A) manufacturers' service division engineer, Vacuum Oil Co., 425 East Water Street, Room 1128, *Milwaukee.*

McCaslin, Henry C. (M) chief engineer, Durant Motors Co. of Canada, Ltd., *Toronto,* (Leaside) *Canada;* (mail) 120 Clifton Road.

McKinley, Moore M. (A) owner, Fremont Electric Co., 744 North 34th Street, *Seattle, Wash.*

Miles, Minnie B., Miss (A) senior engineering aid, War Department, Ordnance, City of Washington; (mail) Raritan Arsenal, *Metuchen, N. J.*

Miller, Gilbert Phillip (J) draftsman, Gramm Motors, Inc., *Delphos, Ohio;* (mail) 214 West Fourth Street.

Miville, Augustine C. (A) proprietor, Toronto Brake Service, 137 Richmond Street West, *Toronto, Ont., Canada;* (mail) 127 Oakcrest Avenue.

Mooney, C. N. (M) service manager, The White Co., 127 Frelinghuysen Avenue, *Newark, N. J.*

Murray, John B. (A) The Texas Co., P. O. Drawer 1115, *Norfolk, Va.*

Mye, George Lai (M) assistant chief engineer, Marchetti Motor Patents, Inc., Russ Building, San Francisco; (mail) 702 Alice Street, *Oakland, Cal.*

Parker, A. L. (M) owner, Parker Appliance Co., 10320 Berea Road, *Cleveland.*

Peterson, E. A. (A) foreman of automobile repairs, Seattle Water Department, *Seattle, Wash.;* (mail) 608 East 63rd Street.

Pfieffer, Alfred Leslie (M) superintendent, garages, maintenance, motor-vehicle repair shop, James A. Hearn & Son, Inc., 20 West 14th Street, *New York City;* (mail) 775 Washington Street.

Reed, Earl W. (A) master mechanic, general foreman of shops, City of Seattle, Fire Department Shops, *Seattle, Wash.;* (mail) 2618 Fourth Avenue, West.

Renno, Arthur A. (A) lubrication engineer, The Texas Co., New York City; (mail) 338 Denniston Street, *Pittsburgh.*

Roberts, Ralph Russell (A) president, Speed Roberts Garage, 1315 East Madison, *Seattle, Wash.*

Ronco, Bunny V. (J) assistant test engineer, International Motor Co., *Allentown, Pa.;* (mail) 608 Cleveland Street.

Roshirt, Randolph J. (M) manager, Bohn Aluminum & Brass Corp., 2599 22nd Street, *Detroit.*

Sargent, Fred L. (M) sales manager, The White Co., Mission Street at 11th, *San Francisco.*

SCHULZE, CARL (J) tool designer, Brown-Lipe-Chapin Co., Subdivision of General Motors, Marcellus Street, *Syracuse, N. Y.;* (mail) Y. M. C. A. 502.

SCOLES, MARIO (M) motor designer, Pierce-Arrow Motor Car Co., *Buffalo;* (mail) 225 Elmwood Avenue, Apartment 25.

SEWARD, RICHARD SAMUEL (A) president, manager, Motor Parts Machine Co., 815 East Pike Street, *Seattle, Wash.*

SHANNON, JAMES F. (A) supervisor of service, Autocar Sales & Service Co., 1168 Commonwealth Avenue, *Boston.*

SMITH, JAMES L. (M) superintendent, motorcoach department, Toronto Transportation Commission, 35 Yonge Street, *Toronto, Ont., Canada.*

SMITH, V. MERTON (A) works manager, Continental Motor Corp., Detroit; (mail) 1403 Kensington Road, *Grosse Pointe, Mich.*

SOLENBERGER, DEAN M. (M) president, Simplex Piston Ring Co. of America, Inc., 1966 East 66th Street, *Cleveland.*

STOCKS, CARL W. (M) editor, *Bus Transportation,* McGraw-Hill Publishing Co., 36th Street and 10th Avenue, *New York City.*

SUMMERS, ROBERT EDWARD (J) instructor in mechanical engineering, Oregon State Agricultural College, *Corvallis, Ore.;* (mail) 404 North 11th Street.

SWARTZ, J. FLEMING (A) service superintendent, Wallace Brothers, 1102 Sprague Avenue, *Spokane, Wash.;* (mail) 314 West 19th Avenue.

TELLER, LOUIS K. (A) general superintendent, maintenance, Rubel Coal & Ice Corp., automobile repair department, 617-659 62nd Street, *Brooklyn, N. Y.;* (mail) 2024 East Fourth Street.

THOMAS, WALDO (A) foreman, automobile repairs, City of Seattle, Municipal Railway Bus Department, *Seattle, Wash.;* (mail) 3711 Carr Place.

THOMAS, WILLIAM GRADY (M) engineer, Southern New England Telephone Co., Engineering Department, *New Haven, Conn.*

TILSHER, GEORGE A. (A) production engineer, Wright Aeronautical Corp., *Paterson, N. J.;* (mail) 26 Sheridan Avenue.

TROMBLY, AUSTIN R. (A) branch manager, Earl B. Staley Co., 201 Adams Street, *Portland, Ore.*

TUCKER, GEORGE H. (A) owner, George H. Tucker, 1828 Franklin Avenue, *Seattle, Wash.*

TUTTLE, JOHN C. (M) Goodyear Tire & Rubber Co., *Akron, Ohio.*

VOLKMAR, WALTER HERBERT (M) general superintendent, Rockford Works, J. I. Case Threshing Machine Co., *Rockford, Ill.;* (mail) 2103 Benderwirt Avenue.

WAGNER, HARRY W. (A) treasurer, Koebel-Wagner Diamond Corp., 342 Madison Avenue, *New York City.*

WESTER, ARTHUR A. (A) president, general manager, Motorcraft Products, Inc., 925 West Fifth Avenue, *Denver.*

WEBSTER, GEORGE P. (A) equipment engineer, Ballou & Wright, 1513 12th Avenue, *Seattle.*

WEBSTER, ROBERT MASSON, JR. (J) draftsman, American Die & Tool Co., Second and Buttonwood Streets, *Reading, Pa.;* (mail) 308 Belvedere Avenue.

WHITE, WILLIAM D. (A) supervisor of production, Perfect Circle Co., *Hagerstown, Ind.;* (mail) 98 North Perry Street.

WHITEMAN, WALTER FRANCIS (J) chief engineer, Monroe Auto Equipment Co., *Monroe, Mich.*

WHITNEY, ALEXANDER (J) electrical draftsman, J. G. Brill Co., *Philadelphia;* (mail) 6643 North Eighth Street, Oak Lane.

WICKWIRE, WARREN E. (A) vehicular supervisor, Continental Baking Co., New York City; (mail) Bakeries Service Corp., 1301 Diversey Parkway, *Chicago.*

WILLIS, REX C. (A) chief engineer, Willis Jones Machinery Co., Inc., 2418 Ninth Avenue, South, *Seattle, Wash.*

WILSON, ALBERT E. (J) draftsman, Hupp Motor Car Corp., *Detroit;* (mail) 6436 Colfax Avenue.

WINTER, P. K. (A) branch manager of service, Wagner Electric Corp., 503 West 56th Street, *New York City.*

WOOD, LYSLE A. (J) draftsman, Boeing Airplane Co., *Seattle;* (mail) 5158 Brighton Street.

WRIGHT, EDWARD D. (A) service manager, Graham-Paige Co. of New England, Boston; (mail) 82 Day Street, *Auburndale, Mass.*

WRIGHT, THEODORE PAUL (M) chief engineer, airplane division, Curtiss Aeroplane & Motor Co., Inc., Clinton Road, *Garden City, N. Y.*

ZIEGLER, EDWIN S. (M) treasurer, Hoover division, York-Hoover Body Corp., *York, Pa.;* (mail) 741 West Market Street.

Applicants for Membership

The applications for membership received between Jan. 15 and Feb. 15, 1929, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ATKINSON, FREDERICK R., president and treasurer, F. R. Atkinson Spring Co., *Hamburg, N. Y.*

BACKUS, TOM, engineer, Willys-Overland Co., *Toledo.*

BEALL, WELLWOOD E., student, New York University, *New York City.*

BEDDOE, H. S., managing director, Carr Fastener Co. of Canada, Ltd., *Hamilton, Ont., Canada.*

BERRY, HAROLD P., tool and process engineer, *Camden, N. J.*

BERRY, HERBERT L., lieutenant, field artillery, United States Army, *Fort Sill, Okla.*

BORN, FRANK G., chief engineer, automotive equipment division, The Wahl Co., *Chicago.*

BOWMAN, ELBERT JOSEPH, technical specialist, General Motors of Canada, Ltd., *Oshawa, Ont., Canada.*

BOYLAN, HENRY WARD, experimental engineer, Detroit Lubricator Co., *Detroit.*

BRACKE, ROBERT F., chief engineer, Vacturi Carburetor Co., *Chicago.*

BRETH, J. P., special representative and salesman, Wayco Oil Corp., *Detroit.*

BULLOCK, GEORGE G., president, Bullock Motor Service, *Chicago.*

BULLOCK, WALTER, general manager, vice-president, Bullock Motor Service, *Chicago.*

CHANT, EMERSON L., final assembly engineer, General Motors of Canada, Ltd., *Oshawa, Ont., Canada.*

CHAPMAN, GORDON BRADLEY, automotive instructor, vocational department, Beverly High School, *Beverly, Mass.*

CHASE, CHARLES H., professor, Engineering School, Tufts College, *Medford, Mass.*

CLARK, M. T., manager, Portland factory, Laher Auto Spring Co., Inc., *Portland, Ore.*

CLEGG, ROBERT J., chassis designer, Packard Motor Car Co., *Detroit.*

DUDLEY, LYNN B., eastern manager, Campbell-Ewald Co., *New York City.*

DUFFY, WILLIAM JOSEPH, vice-president and general manager, Big 3, Inc., *Boston.*

EDSON, MARMONT, sales engineer, The White Co., *New York City.*

FANNING, GEORGE H., New York representative, Fate-Root-Heath Co., *Plymouth, Ohio.*

FARRINGTON, THEODORE ROBERT, instructor in automotive engineering, Board of Education, *Chicago.*

FITZGERALD, T. E., assistant to general sales manager, Mid-Continent Petroleum Corp., *Tulsa, Okla.*

GOODE, GILBERT, research engineer, Chrysler Motors, *Detroit.*

GOSHIMA, SADAJI, aeronautical engineer, Mitsubishi Co., *New York City.*

GRINHAM, EDWARD GEORGE, chief designer, Humber, Ltd., *Coventry, England.*

HARTUNG, WALTER M., aeronautical engineer, Skyward Aircraft Co., *Brooklyn, N. Y.*

HARVEY, J. A., operating engineer, Pittsburgh Motor Coach Co., *Pittsburgh.*

HECK, ELMER H., buyer, Chrysler Motors, *Detroit.*

HEGARD, ALFRED TEIVALA, mechanic, Kedlow Motor Co., *Chicago.*

HENRY, STEPHEN GARRETT, captain, infantry (tanks), instructor, Motor Transport School, United States Army, *Fort Leonard Wood, Md.*

HIGHT, A. GLEN, manager, Mid-West branch, Simplex Piston Ring Co. of America, Inc., *Kansas City, Mo.*

HOLBROOK, FREDERICK OSBORNE, works manager, Perdriau Rubber Co., Ltd., *Drummoyne, Sydney, New South Wales, Australia.*

HOLLAND, STEPHEN J., draftsman, Bendix Brake Co., *South Bend, Ind.*

HOU, JU HSUN, special student, Ford Motor Co., *Highland Park, Mich.*

HUNDSDORFER, GEORGE, vice-president and service superintendent, George D. Grant & Co., Inc., *Seattle.*

IHRIG, A. HENRY, designer, Olds Motor Works, *Lansing, Mich.*

JACQUEY, MARC, engineer, Repusseau & Co., *Levallois-Perret, France.*

JENS, ROLAND C., costs engineer, Minneapolis Steel & Machinery Co., *Minneapolis.*

JUDD, DONALD M., salesman, Ferro Machine & Foundry Co., *Cleveland.*

KINSTLER, LEON L., manager, wheel division, Michigan Steel Casting Co., *Detroit.*

KLEMM, E. RICHARD, JR., president, Klemm Automotive Products Co., *Chicago.*

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Notes and Reviews

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J. Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

AIRCRAFT

Two Practical Methods for the Calculation of the Horizontal Tail Area Necessary for a Statically Stable Airplane. Report No. 293. By Walter S. Diehl. Published by the National Advisory Committee for Aeronautics, City of Washington, 20 pp., illustrated. [A-1]

In 1925 the author began a study of the problem of horizontal tail-surface design. A preliminary survey convinced Mr. Diehl that, although several of the published methods seemed to give good results, they were too complicated for general use. No method was found to combine the qualities of simplicity and accuracy necessary to give it wide use. With these requirements in view, two methods were developed and tested.

The two methods, which are entirely different, have been reduced to simple formulas easily applied to any design combination. Detailed instructions are given for use of the formulas, and all calculations are illustrated by examples. The relative importance of the factors influencing stability is also shown.

Précis de Construction, Calcul et Essais des Avions et Hydravions. By J. Guillemin. Published by Gauthier-Villars et Cie., Paris, France. 442 pp.; 584 illustrations. [A-1]

This exposition on the construction, design and testing of airplanes has behind it the knowledge and prestige to be identified with the author's positions as professor at the College of Aeronautical Engineering and chief engineer of the Hanriot Airplane Co.

His aim has been, to use his own words, first, to give information without wordy discussions, finely spun theories and descriptions of obsolete models; and, second, to set forth with exactness the departments of study in each stage of airplane construction.

From the desire to instruct has arisen the scheme of subject-matter classification. Each chapter leads up to and forms the foundation for succeeding chapters. First to receive consideration are the materials of construction. Their properties are discussed and a number of tables incorporating the more important French standards are presented. Questions affecting the general and detail design of aircraft are next examined. Methods of calculation applicable to aircraft construction and performance are included in the third section. In addition to considering all known aircraft forms, the author makes suggestions that may find application in developments of the future. Practical reflections on operation and control, and directions for aircraft testing, conclude the book.

While the author has forborne to load his book with descriptions of specific commercial models or with quotations from other publications, he has had recourse to authentic sources of information on metallurgy and aeronautics. His aim was to set forth sane fundamental principles, leaving the reader unshackled by traditions to find new and better applications for them.

Sur la Voie de Grand Avion. By A. R. Boehm. Published in *L'Aéronautique*, December, 1928, p. 417. [A-1]

Steadfast adherence to certain basic principles, with continuous and progressive improvements dictated by research, experience and expanding knowledge of materials and methods of handling them, epitomizes the history of the Junkers airplane, according to the author. He dates the beginning of his account from the patent on wing design taken out in 1910, and supplemented in 1918, and reveals glimpses of the future in his references to the features of the giant J-38, 1929 model, now in the course of construction.

Various stages in the development of the basic ideas are typified by the successive types produced: the F-13, constructed in 1919; the G-24, 1925; the W-33, 1926; and the G-31, 1927. Comparative data on dimensions, construction and performance are given for these models and for the J-38, so far as the data are available. In connection with the latest Junkers developments, a system of multiple-wheel landing is described, which, it is claimed, promises better performance on large airplanes than the two-wheel system it is designed to replace. The wheels are arranged in tandem and so suspended that no matter what the inequality of the terrain, each of the wheels included in any one tandem bears an equal share of the landing load.

Bibliography of Aeronautics, 1927. Published by the National Advisory Committee for Aeronautics, City of Washington, 183 pp. [A-3]

This Bibliography of Aeronautics covers the aeronautical literature published from Jan. 1 to Dec. 31, 1927. The first Bibliography of Aeronautics was published by the Smithsonian Institution as Volume 55 of the Smithsonian Miscellaneous Collections and covered the material published prior to June 30, 1909. Supplementary volumes of the Bibliography for the subsequent years have been published by the National Advisory Committee for Aeronautics. They are for the years 1909-1916, 1917-1919, 1920-1921, 1922, 1923, 1924, 1925, and 1926.

As in previous volumes, citations of the publications of all nations are included in the languages in which these publications originally appeared. The arrangement is in dictionary form; with author and subject entry, and one alphabetical arrangement. Detail in the matter of subject reference has been omitted on account of the cost of presentation, but an attempt has been made to give sufficient cross reference for research in special lines.

Practical Flight Training. By Lieut. Barret Studley. Published by The Macmillan Co., New York City; 435 pp., illustrated. [A-4]

No better description of the purpose and content of the book could be given than that included in the author's own preface, as follows:

> Flying cannot be learned from a book. Only time in the air will make a pilot, and the time required to produce a thoroughly experienced pilot runs into hundreds of hours. But the student who, before getting into a plane, has a reasonably clear idea of what he is attempting to learn, will derive considerably greater profit from time in the air than one who has not. The primary object of this book is therefore to explain the details of the various maneuvers of flying. Preliminary study of the theory of these will enable the student to apply himself to their practical execution under guidance of his instructor with a minimum amount of misdirected effort. The printed page can never replace the instructor, but it can assist him.

(*Continued on next left-hand page*)